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The Utility of Embedded Training

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PREFACE

This paper was prepared for the Office of the Deputy Secretary of Defense (Personnel and Readiness) under a task order entitled "Developing a Common Framework for Joint Readiness Assessments." Technical cognizance of this task is assigned to Daniel Gardner.

Carol Denton, Naval Air Warfare Center Training Systems Division, and Bob G. Witmer, Army Research Institute Simulator Systems Research Unit, reviewed an earlier draft of this paper. We acknowledge and appreciate their assistance.

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EXECUTIVE SUMMARY

The objective of this paper is to examine the utility of embedded training (ET) as a contribution to the Quadrennial Defense Review. The following five points summarize the findings:

1. The purpose of ET is to provide effective training to operational units and individuals using operational equipment. ET requires the ability to provide relevant threats and scenarios, assessment of performance, feedback for lessons learned, and collection and management of data on unit training. The "embedded" aspect concerns the incorporation of a training capability in the operational equipment. The choice of whether to embed training must be evaluated on a case-by-case basis, depending on the feasibility and costs of incorporating training in the operational equipment.

2. The main advantage of ET is the ability to train with the same operational equipment that the unit takes to war. Training can take place at home station or while deployed. This type of training has high fidelity, is concurrent with the latest upgrades to the equipment, can be linked to large-scale exercises as the capability of the Defense Simulation Internet (DSI) grows, and permits mission rehearsal and assessment of force readiness. Properly analyzed and configured, ET systems are intended to enhance the use and effectiveness of the operational hardware.

3. The disadvantage of ET is that it may reduce the capability of operational equipment by adding weight, reducing space, and increasing wear and maintenance. Furthermore, when ET functions are being used, the capabilities of the operational equipment may become compromised or unavailable. However, many of the reported disadvantages are often the result of inadequate planning and implementation and are not the necessary result of an effort to embed training.

4. According to user reports identified in our review of the literature, ET is effective and generally acceptable. Nevertheless, little valid and reliable empirical data exist on ET's cost and effectiveness. An effort to collect this information is needed.

5. Army and Navy Service guidance has promoted ET as the preferred training alternative for developing systems. Defense policy should continue to favor ET as a requirement in new weapon systems until it is ruled out in any particular case by careful review of its probable effectiveness and cost. Such consideration from the start of new programs offers the best possibility of training that will optimize the performance and effectiveness of new weapons.

THE UTILITY OF EMBEDDED TRAINING

A. OBJECTIVE AND ORGANIZATION

This document represents a contribution to the Quadrennial Defense Review by examining the utility of embedded training (ET) for military training. We begin by defining ET and identifying different types of ET that have been implemented. Next, we examine past and present interest in the subject and identify advantages and disadvantages of this training method. We then assess new technologies that relate to ET, examine the research on training effectiveness and costs, and identify related areas of research. Finally, we present our conclusions about this approach to training.

The appendixes contain additional information on this topic.

B. DEFINITION OF EMBEDDED TRAINING

ET refers to the use of operational equipment to train personnel assigned to operate and maintain that equipment. ET relies on built-in or easily added-on components, such as computer-based tutorials, simulation scenarios, and software, to sequence material appropriately and to score performance for feedback and lessons learned. This definition is similar to definitions used by the Department of Defense (DoD) and the military Services.

Although the definition of ET is simple and straightforward, it lacks precision because several distinctly different training devices and technologies can be classified as ET systems. To clarify the definition somewhat, training researchers and developers have identified homogeneous subcategories or "types" of ET systems.

The following types of training technologies are commonly considered as examples of ET. This scheme is not intended to provide a definitive classification scheme; rather, it is meant to illustrate the range and variety of training technologies that are considered to be ET systems. Appendix A presents more detailed descriptions of each type, along with some example systems and unique cost-effectiveness considerations.

- **Fully embedded systems.** The prototype ET system, called "fully embedded," has all its training functions built into the operational weapons system.

- **Strap-on (or appended) systems.** Some ET systems use hardware that is added to or connected by cables (umbilical connections) to the operational equipment. This hardware can be planned components of the proposed operational equipment or retrofitted to existing equipment.
- **Practice devices.** Some ET systems provide practice to the exclusion of other training functions. These systems are usually supplemented with instructors or other automated systems to compensate for their limited capabilities.
- **Embedded computer-based tutorials.** These systems are embedded into general-purpose computers for imparting critical knowledge (as opposed to skills). Such tutorials are usually embedded in operational equipment that use general-purpose computers to support complex decision-making.
- **Embedded job or performance aids.** These aids differ from other ET systems because their primary function is to support performance on the job—not to train in preparation for job performance. Nevertheless, embedded job aids and other ET systems share a common goal (performance improvement), are developed from human front-end analyses, and use similar technology for development (Zachary and Hicinbotham, 1994). Examples include embedded aids for maintenance tasks, embedded helps, and embedded decision aids for complex tactical tasks.
- **Certain stand-alone systems.** Stand-alone systems are usually presented as alternatives to ET. However, certain instances of these systems are related to the concept of ET and are even regarded as legitimate instances of ET. This category includes stand-alone systems that
  - are installed on ships,[1]
  - can be linked to embedded training systems by Distributed Interactive Simulation (DIS) technology, and
  - are demonstrations of technologies that eventually may be embedded in operational systems.

Strasel, Dyer, Roth, Alderman, and Finley (1988) stated that ET systems—despite their physical differences—are similar because they share certain common training features or functions. Elaborating on their definitions, we propose that the following training functions are (or should be) common to all ET systems:

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1 Stand-alone training systems on ships are sometimes referred to as "organic" training systems (Stratton et al., 1996).

- presenting appropriate threat scenarios or other relevant information that could occur before or during combat,
- assessing performance,
- providing feedback, and
- collecting and managing training records.

Any evaluation of the effectiveness of ET technology must consider the extent to which it addresses these essential training functions. These training functions also help clarify the definition of ET. Some writers have considered training rounds and training missiles to be examples of ET since they aid training in the actual equipment. However, such training aids do not address these basic functions and are, therefore, not legitimate examples of ET.

For the basic training functions, ET systems do not differ from their stand-alone counterparts—that is, training aids, devices, simulations, and simulators (TADSS). The unique advantage of ET is that the training subsystems are continued in the operational equipment, which is issued to all units and is the material that these units take to war. Moreover, ET provides the capability to use this equipment in its most relevant way at home station or while deployed and avoids the artificiality of going to school or training on representative—but not real—equipment.

C. MILITARY INTEREST IN EMBEDDED TRAINING

Because of these unique advantages, the military has had a continuing interest in ET. As described below, this interest has developed over several years.

1. Early Embedded Training Systems

ET is not a new concept. One of the largest and most successful examples of ET was the Semi-Automatic Ground Environment (SAGE) system that provided training for the Air Force's Air Defense Direction Centers (ADDCs), starting in the late 1950s. Located at 12 sites across the continental United States and Canada, the ADDC's mission was to detect enemy nuclear bombers and to direct aircraft and missiles to intercept them. Embedded in the SAGE system was the capability to train operators by providing synthetic enemy targets to the radar screens. This work started as a series of experiments in team training at RAND (1952–1954) and led to the establishment of the System Development Corporation. This company developed the training program and supplied the "raids" used

for nationwide on-the-job training at the actual direction centers and combat centers that were netted to each other (Parsons, 1972). SAGE developers did not refer to their system as "embedded training," because the term had not yet come into use.

Another example that dates from the early 1960s is the Training Alarm Controller (TAC) that was used to train fire control teams of Polaris submarines. TAC was a fully embedded system that emulated failures in the operational Fire Control System (FCS)—failures that could occur during the countdown before firing a real missile. The TAC activated the actual relays in the FCS to provide appropriate inputs to the fire control team (Annett, 1990). This ET system provides an example of "stimulation" (versus "simulation"), where a signal is injected at or near sensor elements so that the entire operational system is used as it would be used to process a real signal (Hoskin, Jorgensen, Manglass, and Reynolds, 1989).

2. Recent Interest in Embedded Training

Since the 1950s, numerous weapon systems have incorporated ET technology. Hundreds of current systems—many not specifically identified with ET—have some ET capability. In the last 10 years in particular, the interest in ET has increased because of improved technical feasibility, a constrained military budget, and an interest in reducing the costs associated with training. Training costs for simulators, schools, travel, and operating tempo are increasingly visible items in the budget and, consequently, have become targets of opportunity. Training decision-makers increasingly regard ET as a way of reducing costs by incorporating a training capability in the equipment issued to all combat and support units. In this context, the Quadrennial Defense Review offers a timely opportunity to review the utility of ET technology.

In addition to these general economic interests in ET, four specific developments have increased the relevance of ET as a method for delivering training.

a. Computer and Simulation Technology

Simulation and computer hardware technologies have improved tremendously in the recent past (less than 10 years). Improvements in simulation make ET increasingly invisible to the user and maintainer, and DIS standards make it possible to connect ET systems with other training devices within and among units. Micro-miniaturization of electronic components has mitigated the oft-cited problem that ET adds too much weight or takes up too much space in the operational equipment. Software improvements have also enabled

the development of training functions that do not impair or interfere with operational functions of the weapon system. Not incidentally, improvements in materials development and manufacturing have resulted in significant cost reductions for high-technology components. Thus, many ET systems significantly more capable and less expensive than comparable systems designed only 5 to 10 years ago.

b. Instructional Methods

Parallel improvements have been realized in instructional methods. For instance, researchers developed detailed guidance on the incorporation and design of ET systems (e.g., Finley, Alderman, Peckham, and Strasel, 1988; Witmer and Knerr, 1991). Innovations in instructional procedures, such as intelligent tutoring systems, have been embedded in operational systems (e.g., Williams and Reynolds, 1990; Gluckman and Willis, 1994; P.J. Moskal, P.D. Moskal, Carolan, and Chatham, 1994). In addition, several commercial authoring systems that potentially decrease the time and costs related to the development of embedded tutoring systems and decision aids have become available.

c. Training Design and Development

Training designers and developers have become increasingly motivated to endorse ET systems as a preferred method of training. There are at least two reasons for this trend:

1. The adoption, or even simply the consideration, of ET ensures that training is incorporated early in the system development process. Early consideration of training is a major principle for those who ascribe to a systems approach to training development.
2. ET is more likely to stay current with system upgrades than traditional training methods, which are separate from the upgrading process.

d. Military Strategy

DoD's Force Projection Strategy demands that military units be able to deploy rapidly with minimal preparation. With the adoption of ET, units deploy their training capability along with their equipment. This allows units to train in theater and even on their way to the theater. During Operation Desert Storm, Marine Corps units were able to train with the Marine Corps Full-Crew Interactive Simulation Trainer (MCFIST)—an appended ET system for M1 tanks—as they traveled by ship to their deployment site. Although this example may not be representative, it points to the fact that ET systems are consistent with the Force Projection Strategy by providing training to deploying and deployed units.

3. Military Guidance

Current interest in ET has culminated in explicit guidance by the U.S. military on how and when ET technology should be used. Appendix B contains an annotated listing of ET-related policy statements presented by the DoD and the military Services.

The Army and Navy Service policy has favored ET as the preferred training technology. For example, the Navy's *Tactical Training Manual* for the Atlantic and Pacific fleets (CINCLANTFLT/CINCPACFLT, 1996) states that ". . . wherever possible, conduct training on-board ship with organic training devices and installed equipment under supervision of shipboard training teams" (Chapter 5). The Army policy is even more clearly in favor of ET. In 1987, General Maxwell Thurman (then Vice Chief of Staff of the Army) and James Ambrose (then Under Secretary of the Army) issued a memorandum establishing ET as the preferred training technology for developing weapon systems. This concept has been sustained in succeeding Army documents and guidance:

- Army Regulation 350-38, *Training Device Policies and Management*, dated 15 October 1993
- Training and Doctrine Command (TRADOC), *Embedded Training Action Plan*, dated 11 October 1994, and a later version, 3 June 1996, including various messages related to TRADOC Policy (30 March 1995)
- Force XXI, *Warfighter XXI*, dated 9 June 1995
- WarNet XXI, *The WarNet Action Plan*, dated 13 August 1996.

From 1988 to 1991, the Army Research Institute (ARI) issued a 10-volume guide for implementing ET in developing weapons system (Finley, Alderman, Peckham, and Strasel, 1988, and others). Witmer and Knerr (1991) developed abbreviated guidance aimed specifically at the training developer; a second edition was issued in July 1996. The other Services also developed similar guidance during this period:

- The Navy published *Lessons Learned From Currently Fielded Navy Embedded Training Systems* (Hoskin et al., 1989)
- The Air Force published *Research and Development Strategies for Embedded Training* (Walch, Yee, and Burright, 1991)
- Warm, Roth, Sullivan, and Bogner (1988) conducted a tri-Service review of ET: *Tri-service Review of Existing System Embedded Training (ET) Components*.

Clearly, there is no lack of literature on the need for and guidance on how to develop ET.

D. ADVANTAGES AND DISADVANTAGES

Implicit in the concept of ET is the assumption that ET systems offer some distinct advantages over other methods of training. Thus, we identify some of ET's advantages and disadvantages that have been cited in the literature. Some of the advantages and disadvantages are unique to ET, whereas others are shared with other training approaches. Also, we present the disadvantages not so much to argue against the use of ET but, rather, to suggest limiting conditions for the implementation of ET.

Table 1 presents the advantages and disadvantages of ET that relate primarily to training effectiveness. Some of the disadvantages could be interpreted as mirror images of advantages. For instance, the high-fidelity of using actual equipment is tempered by the operational constraints of this equipment. We indicate such complementary relationships by lining up advantages and disadvantages where appropriate.

Table 2 presents the advantages and disadvantages of ET that relate to cost issues. The cost issues provide fewer complementary relationships than the effectiveness issues.

E. ASSESSMENT AND DISCUSSION

We assessed the utility of ET technology based on materials and information retrieved from the Defense Technical Information Center (DTIC) and the World Wide Web. From these sources, we obtained and reviewed 59 technical reports and related documents, which are listed in the bibliography in Appendix C. We also consulted colleagues in the military Services to identify omissions and inaccuracies.

We identified 56 different ET systems used by the three military Services and joint Services and briefly summarized each in Appendix D. This list includes significant historical systems that are no longer used and proposed systems that have yet to be implemented. The current status of many systems could not be determined, so the number of ET systems currently in use is not known. More importantly, Appendix D does not contain information on the numbers and types of DoD Service members trained to determine the total training requirement being met by ET systems. On the other hand, the appendix provides a relatively large and representative sample of military ET systems from which we can derive some generalizations about the state of ET technology.

Each entry in Appendix D includes, at a minimum, a brief functional description of the ET system and the identification of the operational equipment on which the ET system

Table 1. Advantages and Disadvantages of ET Related to Training Effectiveness

Advantages	Disadvantages
Provides high-fidelity training environment (i.e., operational equipment) that promotes transfer of training	Fidelity limited by operational constraints to certain signals and responses.
Promotes increased realism in home station training	Realism limited by ability to mimic actual inputs at home station.
Provides complex environment appropriate for sustainment or continuation training	Complex environment may not be appropriate for initial training.
Training system is deployed with warfighters	Training system is not available if personnel and equipment are deployed separately.
Training system is available or accessible to warfighter at home station.	Accessibility to ET system could be limited for security consideration, maintenance considerations, interference with operational capabilities, or excessive set-up/tear-down time.
Promotes consideration of training issues during design of operational system	Full advantage may not accrue to strap-on ET systems that are added after initial design.
Ensures that training stays current with equipment changes	Advantage may not accrue to strap-on ET systems.
Provides job aiding and decision support as well as training functions, e.g., coaching during maintenance troubleshooting, and rehearsing and wargaming courses of action in command, control, communications, and intelligence (C3I) systems	May degrade performance if job/decision support aids become unavailable (i.e., a performance aid becomes a performance "crutch").
Catastrophic consequences for incorrect responses are minimized if operational and training modes are reliably differentiated	Potential catastrophic consequences exist for incorrect responses if operational and training modes are not reliably differentiated.
Provides systematic variety of scenarios related to unit's mission	Effectiveness limited if capability has not been provided.
Provides performance assessment and feedback	Effectiveness limited if capability has not been provided.
Permits rehearsal of assigned missions	Effectiveness limited if capability has not been provided.
Permits assessment of unit readiness	Effectiveness limited if capability has not been provided.
Can provide training at all levels, from crew to unit to joint	Effectiveness limited if capability has not been provided.
Provides component media for integrating live, virtual, and constructive simulation from unit to world-wide levels	Effectiveness limited if capability has not been provided.

Table 2. Advantages and Disadvantages of ET Related to Cost

Advantages	Disadvantages
Reduces or eliminates costs relative to using a simulated training facility	Increases system development costs
Increases utility of operational equipment by enabling its use during idle periods	Increases system development and maintenance costs
Incurs little or no additional costs for computer-based equipment	Increases system development costs
Reduces requirement for stand-alone simulators	Increases system development costs
Total costs may be reduced by the positive impact of the early incorporation of ET on equipment design and interface issues	Increases system development costs
Reduces costs related to operating tempo (e.g., flying, driving, steaming, shooting)	May increase wear and tear on operational equipment
Can have positive effect on system reliability, availability, and maintenance (RAM) characteristics by improving maintenance testing and training	Can have negative effect on system RAM characteristics by increasing system usage and complexity
Decreases personnel required for sustainment training	Increases personnel required to maintain ET systems
Life-cycle costs of training and training equipment visible in system concept and design	Funds allocated to training subsystem are vulnerable if cost overruns or spending cuts occur during system development
	Increases costs for "ruggedizing" ET system
	Adds weight and/or take up space in operational equipment
	May require additional or auxiliary equipment (e.g., generators)
	Cost analysis of ET must include life-cycle equipment costs that are not directly related to training.
	Costly to modify training courseware that is tied to tactical software

is implemented (the "parent" system). In most cases, the ET system has a name separate from its parent system, but, in some cases, the ET system is not distinguished from the system in which it is embedded. As described below, some ET systems had additional information concerning user assessments of the system and positive features of the system.

In addition to identifying the details of specific ET systems, our review revealed some generalities about ET methods. These generalities address issues related to technology, effectiveness, and costs.

1. Technological Opportunities

ET is not a unitary technology but rather a diverse collection of technologies that address a common purpose: training on operational equipment. Emerging technologies, in particular, have provided opportunities for new concepts in ET. Examples include:

- **The On-Board Electronic Warfare Simulator (OBEWS).** The OBEWS uses an electrically erasable, programmable read only memory (EEPROM) module to generate in-flight threat scenarios and to record performance for debriefing on the ground.
- **The World-Wide Military Command and Control System (WWMCCS).** The WWMCCS is implemented on general-purpose computers. These computers provide an inexpensive platform for implementing embedded tutorials.
- **The AEGIS Combat Training System (ACTS).** ACTS incorporates local and wide area networking of systems to allow homogeneous teams and disparate units to practice in realistic combat exercises.
- **The Organic Combat System Training Technology (OCSTT).** OCSTT incorporates DIS technology, which allow this ET system to interact with other live, virtual, and constructive simulations.

2. Effectiveness

The effectiveness of ET is properly defined as the extent to which an ET system results in or contributes to improved performance on the parent system. Except for a few cases, our review failed to reveal effectiveness data based on operational equipment. Although performance data provide the most valid basis for determining training effectiveness, such data are sometimes difficult and expensive to obtain. Walch, Yee, and Burright (1991) have described the dilemma of collecting performance-based effectiveness data as follows: When effectiveness data are most needed (i.e., during initial system development), these data do not exist; when valid performance data become available (i.e., after fielding), users no longer need these data to justify the system.

Given the problems with obtaining performance data, training researchers and developers instead have used a variety of other measures that relate to training effectiveness, such as subjective judgments of effectiveness, assessments of user friendliness, and the frequency or amount of usage. Although such subjective data are related to aspects of training effectiveness, these data are clearly a less-than-desirable substitute for objective performance data.

We were successful in finding evidence related to the effectiveness of 26 of the 56 systems that we initially identified, although, in most cases, the evidence was based on subjective appraisals as opposed to objective performance. (The evidence is summarized in the part of Appendix D labeled "Assessment.") For each system that received such an assessment, we also identified features that some have identified as possibly contributing to (positive features) or detracting from (negative features) the effectiveness of the ET system. These features relate directly to the common training functions of ET systems identified at the beginning of this document. Table 3 presents some of the more prevalent positive and negative features that we identified.

Table 3. Common Positive and Negative Features on ET Systems

Positive Features	Negative Features
Ability to author custom scenarios	Problems or limitations in simulation fidelity
Access to library of "canned" scenarios	Reduction in or interference with operational capabilities
Ability to interface with other related systems for full-team training	Lack of performance measurement capability
Ability to mix live and simulated targets	Unacceptable time and effort required to switch between operational and training modes
Provision of individualized instruction by embedded tutors, requiring little or no supervision	Lack of documentation for ET system
Ability to emulate system inputs realistically	Increase in maintenance and logistics requirements

Of the 26 ET systems for which we had effectiveness information, 21 (81 percent) received overall favorable assessments. In six instances, however, the favorable assessments were qualified because users noted some aspects of the systems that they felt detracted from training effectiveness or because positive assessments were only based on preliminary tests of the system. Favorably assessed systems had few specific positive features in common. However, they shared two general positive characteristics: they were reliable training systems, and their parent systems were generally available for training.

For the unfavorably assessed systems, no single feature or type of feature stood out. Interestingly, negative assessments did not appear to be related to the system's training features. For instance, the Performance Measurement and Evaluation (PME) for sonar systems of surface ships received an unfavorable assessment even though it is instructionally sound. Its problem was an inability to provide training without other devices. Instead, negative assessments appeared to pertain to logistical or operational considerations. Two examples include the TPQ-29 Trainer for the Improved HAWK (IHAWK) Missile System, which is especially difficult to set up and tear down, and the

Operational Training Software (OTS) for simulating EW targets on surface ships, which interferes with operation of the AN/SLQ-32 console. Thus, the negative assessments did not indicate a disapproval of ET concepts; rather, they appeared to result from inadequate planning and implementation of ET systems.

3. Costs

Two similar approaches to analysis of ET costs are relevant. Knapp and Orlansky (1983) describe a generic cost element structure for training course, procedure, or device. Their major cost categories include costs related to research and development (R&D), initial investment, and operation and support. Individual cost elements are defined within these three categories. Witmer and Knerr (1996) suggested a similar scheme with four categories of costs related to design and development, procurement, maintenance, and operations. Both approaches provide a comprehensive scheme for identifying costs related to the development and implementation of ET systems.

Cost information was available on only 7 of the 54 ET systems that we identified. Table 4 summarizes this information. As shown, these studies considered a variety of costs, including initial cost, operating cost, cost comparisons, and cost avoidances. As shown in Table 4, the costs examined in these seven studies present a variety of methods and details concerning costs. Because of the unique nature of these findings, each is described below as a case study in cost analysis. Although these studies examined different types of costs, they were consistent in their suggestion that savings that may result from implementing ET.

a. Advanced Embedded Training (AET)

AET, an R&D project for the Naval Air Warfare Center (NAWC), is part of an Advanced Technology Demonstration (ATD) to integrate human performance technologies in the AEGIS Combat System and Combat Training System. The eventual product will provide an adjunct to ACTS. The R&D Project Summaries for FY 1997 (NAWC, 1996) provided the following estimated cost savings but did not include costs to develop and implement the AET.

The AET system will significantly reduce the requirements for assignment of Afloat Training Organizations and AEGIS Training Support Group training support personnel to ships, which could result in a \$1.5M/year cost savings. Moreover, the expected level of

Table 4. Summary of Cost Findings Related to ET Systems

ET System	Costs Considered	Estimated Savings	Reference(s)
AET	Estimated personnel costs are related to training effectiveness.	Estimated reduction in training support personnel could save $1.5M per year, and increase team performance 25 to 40 percent.	(Naval Air Warfare Center, 1996)
Proposed ET System for Emerging Fighter Aircraft	Estimated operating costs are related to training efficiency.	3X increase in training events could be achieved for 1.2–1.4X increase in costs.	O'Brien and Hess (1988a, 1988b, 1988c, and 1988d)
OBEWS	Comparison of initial investment costs of ET system to parent system.	Total acquisition cost for OBEWS ($121M) is less than the cost of a single advanced combat aircraft.	Senate Appropriations Committee (1995)
Onboard Simulation (OBS) for the F-15B	Actual cost savings in developing system software and operating equipment during operational test of parent system are related to actual costs to develop ET system.	Savings in software development costs was $6.3M, and savings in test operation was $351K. In comparison, the cost of OBS development was $1.2M.	Kocher (1984)
OCSTT	Comparison of initial investment costs of similar systems is related to functionality.	OCSTT, costing less than $200K, replaces Device 20B5, costing $10M per unit. The 20B5 is an umbilical pierside ET system, whereas the OCSTT is an onboard system that provides about 70 percent of the 20B5 functions.	Stratton et al. (1996)
SPA-25G Embedded Training System (SETS)	Avoidance of wasted training costs.	Based on an estimated drop in attrition in Navy schools, SETS may save $870K per year.	Lacy, Ellis, and Madden (1990)
Tank Weapons Gunnery Simulation System (TWGSS) and Precision Gunnery System (PGS)	Avoidance of live-fire training costs.	Reductions to live ammunition costs saves about $13M annually for each system.	B. Harrison (personal communication, March 1997)

training enhancement is a 25 to 40 percent step improvement in team performance, as determined by validated measures of effectiveness.

b. Embedded Training for Emerging Fighter Aircraft

Dynamics Research Corporation produced a four-volume document for the Air Force Aeronautical Systems Division (ASD). This document describes methods for determining ET technology in emerging systems (O'Brien and Hess, 1988a, 1988b, 1988c, and 1988d). One of the emerging systems they examined was the F-16C, a (then) near-term aircraft scheduled to become operational in the 1987–1993 timeframe. A central component of the model was a method for projecting the operational costs of ET. One of their training models assumes that pilots mix ET and live training events (i.e., maneuvers) during training missions. The analysts asserted that pilots could fit in twice as many ET events as live events during the same period of time required to perform the live events alone. In other words, O'Brien and Hess contend that their proposed ET training system would realize savings by making training more efficient.

To cost out these events, O'Brien and Hess (1988c) developed two models: one for training without ET and one for training with ET. The major cost elements for training without ET included aircraft flying hours, gun rounds, bombs, and missiles. The elements for training with ET included flying hours but did not include gun rounds, bombs, and missiles, and it added costs for "wear and tear" on avionics, ground planning and debriefing, software, and ET operation. Analysis of the previous "mixed scenario" showed that a large increase in events (in effect, tripling the number of trials) could be achieved by a relatively modest increase in total costs (20 to 40 percent). This analysis implies that the proposed ET system would be cost effective if simulated trials provide at least 20 to 40 percent of the benefit of live trials—a modest expectation for the effectiveness of the system.

c. On-Board Electronic Warfare Simulator

Some data exist on system acquisition costs for the OBEWS. During their deliberations on the FY 1995 budget, the Senate Appropriations Committee (SAC) compared the costs of acquiring OBEWS to the costs of acquiring its parent system:

> The Committee notes that the total acquisition cost for OBEWS was estimated to be \$120,600,000 for approximately 900 aircraft systems and 40 squadron debriefing stations. That amount is less than the probable cost of a single advanced combat aircraft in the future (SAC, 1995, p. 287).

d. Onboard Simulation for the F-15B

The F-15B OBS is a fully embedded training system that presents simulated targets in the pilot's heads-up display (HUD). Kocher (1984) documented the costs saved during operational testing of the Integrated Flight and Fire Control (IFFC) system on the F-15B. The original concept of the OBS was to serve as a replacement for and improvement on a ground-based test unit that would send signals to the aircraft subsystems. During IFFC development, the OBS was used as a man-in-the-loop simulation to develop and debug software. Kocher figured that using OBS reduced the man-hours per computer word from 8 to 3.5. This resulted in a savings of about \$7.5M. Subtracting the cost to develop OBS (\$1.2M), the total savings in software development amounted to \$6.3M.

OBS also reduced the operational costs of IFFC flight testing in two ways.

1. OBS reduced expenses related to using real targets. These expenses included the cost of ammunition and bombs and cost per hour to operate additional aircraft to provide or tow targets.
2. OBS greatly increased the number of events that can be trained per flight hour because of its ability to reset conditions instantaneously after a simulated weapon encounter to prepare for the next encounter.

In comparison, lengthy set-up times are required between encounters using real targets. On average, OBS provided 39.8 events per hour, whereas tactical (nonfiring) training averaged 16.3 events and live-fire training averaged 5.3 events. Total savings were calculated assuming that actual OBS events were replaced by tactical events. The actual savings was about \$351K.

Finally, the total savings attributable to OBS (about \$6.6M, including software development and operational costs) were compared to the cost to develop OBS (\$1.2M). In other words, the savings realized were 5.5 times the costs required to develop the ET system.

e. Organic Combat System Training Technology

NAWC's Training Technical Division has developed the OCSTT as a technology demonstration for showing how modern off-the-shelf digital processing technology can be used to provide combat training capability aboard ship (Stratton et al., 1996). OCSTT represents a modernization of Device 20B5, which is an umbilical pierside system for training combat teams on FFG-7 class surface ships. The OCSTT provides the capability to train about 70 percent of the functions trained by Device 20B5 at sea. The redesigned

system is also compatible with DIS standards so that it can be incorporated into the Battle Force Tactical Trainer (BFTT), a Navy project for linking different training systems via wide area networking. Moreover, the OCSTT provides these training capabilities at substantially lower investment costs: a single production 20B5 costs in excess of $10M, whereas the OCSTT costs less than $200K. This provides a demonstration of how modern digital technology is greatly decreasing the costs of ET.

f. SPA-25G Embedded Training System

SETS trains individual operator tasks in four task areas: equipment proficiency, radar navigation, air intercept control, and anti-submarine air control. According to Lacy, Ellis, and Madden (1990), instructors in the Navy "C" school for air controllers estimate that SETS could reduce attrition by 50 percent. The annual throughput at the school is 58 students, and training costs approximately $30K per student. Thus, using SETS avoids $870K per year (29 × $30K) in potentially wasted training funds.

g. Tank Weapons Gunnery Simulation System and Precision Gunnery System (TWGSS)

The Army's Simulation Training and Instrumentation Command (STRICOM) has provided cost data related to the TWGSS and the PGS (B. Harrison, personal communication, March 1997). The TWGSS is an appended ET system for the M1-series battle tank. TWGSS uses a laser emission system to simulate the effects of precision firing of the 120-mm main gun and coaxial machine gun for force-on-force (FOF) tactical training. The PGS is an analogous system for the Bradley Infantry Fighting Vehicle and simulates the effects of the 25-mm main gun, coaxial machine gun, and the Tube-launched, Optically-tracked, Wire-guided (TOW) missile.

The basis of issue (BOI) for TWGSS is one per platoon (four tanks). The annual allocation of practice ammunition for each tank crew in a platoon receiving TWGSS is reduced by 10 rounds. Main gun rounds cost approximately $600 each. Assuming that 2,166 active duty tanks are in the inventory, the Army avoids nearly $13 million in main gun ammunition costs. This analysis does not include the costs and savings of ammunition for the coaxial machine gun nor does it include the costs of buying and using TWGSS.

A similar analysis can be performed on PGS. Each Bradley crew is getting cut 192 rounds at $30 each. Given approximately 2,200 Bradleys in use, the cost avoidance related to main gun ammunition is $12.7 million. This does not include potential avoidance

of coaxial machine gun ammunition and TOW missiles costs. Potential cost avoidance in TOW missiles is great, given that TOWs cost approximately $12,000 each. However, crews fire very few of these missiles. As in TWGSS, this analysis overlooks the costs of buying and using PGS.

4. Research on Related Technologies

There is a dearth of empirical research on the effectiveness and costs related to ET; however, there is a substantial body of research on stand-alone, computer-based instruction (CBI) and simulator training. Because the training functions and technologies are common to stand-alone and ET methods, this empirical research base is relevant to the evaluation of ET. In that regard, we offer the following four summary points, which are based on over 100 studies of computer-based training systems.

1. CBI is as effective as classroom instruction (i.e., students learn as much) and saves about 30 percent of the time needed for conventional instruction. The main reason for this effect is that students proceed at their own rates of learning and that most of the students are not restrained by the slower learning rates of some students (Orlansky and String, 1979).
2. CBI improves performance so that the average student performs like those at the 69th percentile of those using conventional instruction (Fletcher, 1990).
3. Pilots who use flight simulators for training initial flying tasks save about half the flight time needed to train the same tasks in an aircraft. The cost per hour of using a simulator for training is about 10 percent of what it costs to use an equivalent airplane. Thus, the use of flight simulators for training is highly cost-effective and enhances training in the aircraft (Orlansky et al., 1994).
4. The use of computer-based guidance for maintaining F-16 aircraft, compared to the use of conventional paper-based technical orders, increased the percent of maintenance problems solved successfully, reduced the time needed to complete maintenance actions and order spare parts, and reduced the number of errors per problem for specialists and nonspecialists. In fact, technicians using computer-based guides performed better than specialists using paper-based technical orders. The use of computer-based maintenance for the F-16 was estimated to save about $21.6M per year (FY 1995 dollars), about 0.5 percent of the annual budget for operations and maintenance of the F-16 alone (Teitelbaum and Orlansky, 1996).

F. FINDINGS

The purpose of ET is to provide effective training to operational units and individuals using operational equipment. ET requires the ability to provide relevant threats and scenarios, assessment of performance, feedback for lessons learned, and collection and management of data on unit training. The "embedded" aspect concerns the incorporation of a training capability in the operational equipment. The choice of whether to embed training must be evaluated on a case-by-case basis, depending on the feasibility and costs of incorporating training in the operational equipment.

The main advantage of ET is the ability to train with the same operational equipment that the unit takes to war. Training can take place at home station or while deployed. This type of training has high fidelity, is concurrent with the latest upgrades to the equipment, can be linked to large-scale exercises as the capability of the Defense Simulation Internet (DSI) grows, and permits mission rehearsal and assessment of force readiness. Properly analyzed and configured, ET systems are intended to enhance the use and effectiveness of the operational hardware.

The disadvantage of ET is that it may reduce the capability of operational equipment by adding weight, reducing space, and increasing wear and maintenance. Furthermore, when ET functions are being used, the capabilities of the operational equipment may become compromised or unavailable. However, many of the reported disadvantages are often the result of inadequate planning and implementation and are not the necessary result of an effort to embed training.

According to user reports identified in our review of the literature, ET is effective and generally acceptable. Nevertheless, little valid and reliable empirical data exist on ET's cost and effectiveness. An effort to collect this information is needed.

Army and Navy Service guidance has promoted ET as the preferred training alternative for developing systems. Defense policy should continue to favor ET as a requirement in new weapon systems until it is ruled out in any particular case by careful review of its probable effectiveness and cost. Such consideration from the start of new programs offers the best possibility of training that will optimize the performance and effectiveness of new weapons.

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GLOSSARY

2-D	two dimensional
3-D	three dimensional
AAR	After-Action Review
AAWC	anti-aircraft warfare coordinator
ABCS	Army Battle Command System
ACE	Air Combat Evaluator
ACTER	Anti-Countermeasures Trainer
ACTS	AEGIS Combat Training System
AD	air defense
ADA	Air Defense Artillery
ADDC	Air Defense Direction Center
ADSIM	Automatic Detection Tracking System Simulation
ADT	Automatic Detector Tracker
AET	Advanced Embedded Training
AFATDS	Advanced Field Artillery Tactical Data System
AFCS	Automated Fire Control System
AFIST	Abrams Full Crew Interactive Simulator Trainer
AGES	Air Ground Engagement System
AIMS	Automated Information Management System
AMRAAM	advanced medium range air-to-air missile
AOCP	Airborne Operational Computer Program

ARI	Army Research Institute
ARI	Army Research Institute
ARTEP	Army Training and Evaluation Plan
ASAS	All Source Analysis System
ASD	Aeronautical Systems Division
ASE	Aircraft Survivability Equipment
ASET	Aircraft Survivability Equipment Trainer
ASG	Advanced Scenario Generator
ASW	anti-submarine warfare
ATAS	Advanced Tank Armament System
ATCSS	Army Tactical Command and Control System
ATD	Advanced Technology Demonstration
AWACS	Airborne Warning and Control System
AWS	anti-submarine warfare
BATR	Bullets-At-Target-Range
BFACS	Battlefield Functional Area Command and Control Systems
BFTT	Battle Force Tactical Trainer
BIN	BFTT Information Net
BIT	built-in test
BOI	basis of issue
C&D	command and decision
C/NET	Chief of Navy/Naval Education and Training
C2	command and control
C3I	command, control, communications, and intelligence
C4I	command, control, communications, computers, and intelligence

CAI	computer-assisted instruction
CAST	Computer-Aided Submode Training
CBI	computer-based instruction
CBT	computer-based training
CD	compact disk
CIC	Combat Information Center
CINC	Commander in Chief
CINCLANTFLT	Commander in Chief, Atlantic Fleet
CINCPACFLT	Commander in Chief, Pacific Fleet
CJTF	Combined Joint Task Force
CNO	Chief of Naval Operations
CO	Commanding Officer
COACH	Computerized On-line Advising and Contextual Help
COE	common operating environment
COTS	commercial off-the-shelf
CP	capabilities package
CSC	combat systems coordinator
CSS	combat service support
CSSCS	Combat Service Support Command System
CSTS	Combat Simulation Training [formerly, Test] System
CTC	Combat Training Center
D-FIRST	Deployable Force-on-Force Instrumented Range SysTem
DIS	Distributed Interactive Simulation
DoD	Department of Defense
DoDIIS	DoD Intelligence Information System
DOS	Disk Operating System

DSI	Defense Simulation Internet
DTIC	Defense Technical Information Center
ECCM	electronic counter-countermeasure
ECM	electronic countermeasure
EEPROM	electrically erasable, programmable read only memory
ENSCE	Enemy Situation Correlation Element
EO	Executive Officer
ESM	electronic support measure
ET	embedded training
EW	electronic warfare
EWIET	Electronic Warfare Intelligent Embedded Training
EWS	electronic warfare supervisor
FAAD C2I	Forward Area Air Defense, Command, Control, and Intelligence
FCS	Fire Control System
FM	field manual
FY	Fiscal Year
GFCS	Gun Fire Control System
GPS	Global Positioning System
GSS	ground support subsystem
HAWK	Homing All-the-Way Killer
HIP	Howitzer Improvement Program
HIP ET	Howitzer Improvement Program Embedded Training
HUD	heads-up display
I-TS	Improved Target Acquisition System-Training System
ICW	Interactive Courseware

IDC	identification coordinator
IEOA	Intelligent Embedded Operator Assistant
IFCC	Integrated Flight and Fire Control
IFF	identification friend or foe
IFT	In-Flight Trainer
IHAWK	Improved HAWK
IMAT	Interactive Multisensor Analysis Training
IMIS	Integrated Maintenance Information System
INDEX	Independent Exercises
IOT	Integral Operator Trainer
ITAS	Improved Target Acquisition System
Janus	large combat model (constructive simulation)
JCMT	Joint Collection Management Tools
JCPMS	Joint Communications Planning and Management System
JMCIS	Joint Maritime Command Information System
JSIMS	Joint Simulation Systems
JTF	Joint Task Force
KOALAS	Knowledgeable Observation Analysis-Linked Advisory System
L-TRAN	Lesson Translator
LAMPS	Light Airborne Multi-Purpose System
LAT	Live Air Trainer
MCFIST	Marine Corps Full-Crew Interactive Simulation Trainer
METT-T	mission, enemy, troops, terrain, and time
MFCS	Missile Fire Control System
MILES	Multiple Integrated Laser Engagement System

NAWC	Naval Air Warfare Center
NRL	Naval Research Laboratory
NTCS	Navy Tactical Command System
NTDS	Navy Tactical Data System
O/C	observer/controller
OBEWS	On-Board Electronic Warfare Simulator
OBS	Onboard Simulation on-board subsystem
OCSTT	Organic Combat System Training Technology
OPNAVINST	Operational Navy Instruction
ORATS	Operational Readiness Assessment and Training System
OTS	Operational Training Software
PAL	Presentation Authoring Language
PARS	Patrol Analysis Recording System
PC	personal computer
PGS	Precision Gunnery System
PMA	Portable Maintenance Aid
PME	Performance Measurement and Evaluation
PPI	Plan Position Indicator
R&D	research and development
RADDS	Radar Display and Distribution System
RAM	random access memory reliability, availability, and maintenance
RCS	Radio Communications System
REES	Radar Electromagnetic Environmental Simulator
RESS	Radar Environment Simulator System
RIO	radar intercept officer

ROM	read only memory
RPV	Remotely Piloted Vehicle
RWR	radar warning receiver
S&T	Science and Technology
SAC	Senate Appropriations Committee
SAGE	Semi-Automatic Ground Environment
SAS	Surveillance and AIMS System
SDC	situation display console
SETS	SPA-25G Embedded Training System
SOR	State of Readiness
ST	Sonar Technician
STAMIS	Standard Army Management Information Systems
STOW	Synthetic Theater of War
STP	Systems Training Program
STRICOM	Simulation Training and Instrumentation Command
STSS	Sonar Target Signal Simulator
STX	Situational Training Exercise
TAC	Training Alarm Controller Tactical Air Command
TACFIRE	Tactical Fire Direction System
TADSS	training aids, devices, simulations, and simulators
TAO	tactical action officer
TCG	Training Coordination Group
TES	Tactical Engagement Simulation
TI	Texas Instruments
TIC	tactical information coordinator

TIU	Training Interface Unit
TM	technical manual
TOW	Tube-launched, Optically-tracked, Wire-guided missile
TPT	Troop Proficiency Trainer
TRADOC	Training and Doctrine Command
TRASANA	TRADOC Systems Analysis Activity
TT&P	tactics, techniques, and procedures
TWGSS	Tank Weapons Gunnery Simulation System
UFCS	Underwater Fire Control System
VSS	Video Signal Simulator
WCS	Weapons Control System
WDS	Weapons Direction System
WEO	Weapon Engineer Officer
WF	Warfighter
WSRT	Weapon Systems Readiness Test
WWMCCS	World-Wide Military Command and Control System

APPENDIX A.
TYPES OF EMBEDDED TRAINING SYSTEMS, WITH EXAMPLES

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TYPES OF EMBEDDED TRAINING SYSTEMS, WITH EXAMPLES

Our definition of ET includes many different types of technologies, each with unique aspects of effectiveness and cost. The following is an attempt to identify different types of ET systems and their associated features. Its purpose is not to provide a mutually exclusive classification scheme but, rather, to identify the various technologies that can provide ET functions. To make these categories more concrete, we have included some examples,

A. FULLY EMBEDDED SYSTEMS

The prototype ET system, called "fully embedded," has all of its training functions built into the operational weapon system. The ideal, fully embedded training system provides high-fidelity simulated scenarios along with automated training support, including performance measurement and feedback capabilities. Although this is the most comprehensive form of ET, it is usually limited in scope to the most highly critical aspects of combat engagements. No ET system can or pretends to provide all necessary system training. Functionally, fully embedded training systems are not different from training simulators, which have been shown to be cost-effective means of delivering training (Orlansky et al., 1994).

Although the fully embedded form is the most often described and almost universally endorsed type of ET, there are surprisingly few fielded examples of this category:

- **The Troop Proficiency Trainer (TPT).** The TPT is embedded in the Army's PATRIOT Missile System. The TPT simulates actual PATRIOT data while disabling the radar system. Each battery can train individually or be networked to simulate battalion-directed air defense functions.
- **The Airborne Operational Computer Program (AOCP).** The AOCP is embedded in the Air Force's Airborne Warning and Control System (AWACS). The AOCP presents simulated scenarios on- or off-line. If on-line, the ET is automatically deactivated when AWACS receives an alert.

- **The AEGIS Combat Training System (ACTS).** ACTS is embedded in the Navy's AEGIS Weapon System. ACTS uses simulation scenarios to train command and decision-making, Weapons Control System (WCS) functions, and Fire Control System (FCS) functions. ACTS trains all Combat Information Center (CIC) stations and can be used for multi-ship training by transmitting computer-generated symbols and raw video to other participants.
- **The Battle Force Tactical Trainer (BFTT).** The BFTT provides tactical training, on a part basis, by linking fully embedded systems of surface, subsurface, and air forces for a world-wide synthetic theater of war (STOW). Training capability includes timely feedback. This system is currently under development.

B. STRAP-ON (OR APPENDED) SYSTEMS

Strap-on ET systems use hardware that is added or appended to the operational equipment to make it more useful for training. There are two types of strap-on systems, which differ in whether they are incorporated into the initial design of the equipment or are retrofitted after the equipment is designed and implemented.

1. Integrated Strap-On Systems

This type of system refers to appended systems that are planned for and integrated into the operational equipment. Even though the ET system is external to the equipment, this form of strap-on ET is a planned component of the equipment. This sort of strap-on system does not differ functionally from fully integrated ET systems. The following examples of this type are provided:

- **The Tank Weapons Gunnery Simulation System (TWGSS).** The TWGSS was designed to be ported into the FCS of the M1A2 tank. This particular example is sometimes used as an example of an "umbilical" ET system because it has physical connections that are embedded in the operational equipment.
- **The Training Interface Unit (TIU).** The TIU for the Aquila Remotely Piloted Vehicle (RPV) straps onto the system to provide the additional computing capacity needed to run a computer-generated simulation through the Aquila system displays.

2. Post Hoc Strap-On Systems

Post hoc strap-on ET systems are those systems that are developed independently from and often after the design of the operational equipment. This category includes ET systems that have been retrofitted to existing operational equipment. The following examples are pertinent:

- **The On-Board Electronic Warfare Simulator (OBEWS).** OBEWS was designed to simulate electronic warfare (EW) targets in F-16s. The strap-on component is a "pod" mounted under the wing. It interacts with the aircraft's radar system to produce appropriate signals.
- **The Multiple Integrated Laser Engagement System (MILES).** MILES is used on armored vehicles but does not physically interact with the FCS of the tank. It is embedded only in the sense that MILES is a system that employs the operational system to provide training.

C. PRACTICE DEVICES

Ideally, ET systems should provide performance assessment and training management capabilities in addition to the opportunity to practice. Practice devices refer to ET systems that provide practice to the exclusion of other training functions. The following examples are ET strap-on systems that provide only practice capabilities. Note, however, that these systems are normally supplemented with others to compensate for their limited capabilities.

- **MILES.** MILES is designed to provide practice in force-on-force (FOF) engagements. It does not provide instruction on tactics, performance measurement capabilities, or feedback. MILES is often used in the context of a Situational Training Exercise (STX) to provide the battle scenario context and performance scoring and feedback procedures for observer/controllers (O/Cs). STXs are part of the text-based Army Training and Evaluation Plan (ARTEP).
- **Unit 34.** Unit 34 generates sonar targets on AN/SQS-53 sonar consoles and Navy Tactical Data System (NTDS) consoles on surface ships. Unit 34 is sometimes used with the Operational Readiness Assessment and Training System (ORATS) structured training package, which provides the missing instructional components to this ET system.

D. EMBEDDED COMPUTER-BASED TUTORIALS

Some types of operational equipment employ general-purpose digital computer technology to support complex decisions related to command and control (C2) and fire

direction. Such systems are usually capable of running standard computer-based tutorials, which could be authored using conventional off-the-shelf software. Functionally, these tutorials are not different from conventional computer-based training (CBT), a technology demonstrated to be cost-effective (Orlansky and String, 1979; Fletcher and Orlansky, 1989). This approach can be particularly cost-effective if the operating system of the computer-based system is compatible with CBT authoring systems. In that case, the cost of developing new training programs would be low. Examples of computer-based tutors include the following:

- **The prototype tutorial system for the Air Force's Sentinel Byte.** The Sentinel Byte is a command, control, communications, and intelligence (C3I) system for planning air routes and analyzing air defense threats.
- **The computer-based tutorials embedded in the older Joint Services World-Wide Military Command and Control System (WWMCCS).** A unique capability of this system is that tutorials can run at some stations while the system is operating on others.
- **The computer-based tutorials in the Tactical Fire Direction System (TACFIRE).** These tutorials were developed by the Army Research Institute (ARI) in the PLANIT authoring language.

E. EMBEDDED JOB OR PERFORMANCE AIDS

Job or performance aiding is considered to be a separate topic from training. However, when job aids for complex cognitive tasks (often called "decision aids") are embedded in operational equipment, these job aids closely resemble ET systems. Zachary and Hicinbotham (1994) contend that the major similarities of ET and embedded decision aids are that both of them focus on human performance improvement, are designed from human front-end analyses, and use similar technology for development.

On-line helps are simple (even trivial) examples of embedded job aids and are implemented on several embedded tutorials, particularly for maintenance tasks. These types of aids resemble those implemented on commercial software. Perhaps more interesting are embedded performance aids for complex cognitive tasks. However, these technologies are only at the proposal stage of development. The following are some hypothetical examples, which represent straightforward extensions of extant technology.

1. On-line Coaching

It has been proposed that maintenance test equipment coach the performer through troubleshooting steps as he performs the actual test. The proposed system called Computerized On-line Advising and Contextual Help (COACH) appears to provide some of these functions as an embedded feature of the Portable Maintenance Aid (PMA). The PMA is small ruggedized component of the Integrated Maintenance Information System (IMIS) that is designed to aid in flightline maintenance. COACH embeds an advisor (the "Coach") in the PMA to help the technician solve simulated problems in training. While COACH can be used in the flightline maintenance environment, the developers caution against using it during actual maintenance operations (Wilson, Walsh, Arnold, and Daly, 1996). Ironically, then, COACH may be a better trainer than a job aid.

2. Decision Aiding

It has also been proposed that C3I information management systems incorporate complex decision aids—even including the capability to wargame actions during preparation for a battle. This function is projected for the Interactive Multisensor Analysis Training (IMAT) simulation of anti-submarine and EW effects. However, development of this capability assumes that the present land-based demonstration will be converted to an operational on-board (i.e., embedded) system.

3. Rehearsal

Taken a step further, constructive simulations [e.g., Janus, Joint Simulation Systems (JSIMS)] could be incorporated into C3I systems to simulate battlefield effects. Such a system could provide battle staffs the capability to rehearse planned actions during preparation for a battle.

F. CERTAIN STAND-ALONE SYSTEMS

Stand-alone systems are usually considered alternatives to—rather than examples of—ET systems. However, a few specialized types of stand-alone training systems are closely related to the concept of ET.

1. Shipboard Training Systems

The Navy considers almost any training system mounted on ships as providing ET. This is consistent with guidance from the Chief of Naval Operations (1991) as cited by the

Naval Surface Warfare Center (1996) that ". . . the ship, when properly supported, presents the most effective training site for appropriate operational and functional training." This would include shipboard computer-based tutors, training devices, and constructive simulations. Compared to other military systems, there is less penalty to pay for the weight and space of a stand-alone training system on a ship, particularly one that is pierside.

2. Distributed Interactive Simulation (DIS) Systems

Certain DIS systems are related to ET to the extent that they allow or promote training with the operational equipment. An example of such a DIS-based system is the Army National Guard's Deployable Force-on-Force Instrumented Range SysTem (D-FIRST). D-FIRST is an instrumented range system, which is based on existing Global Positioning System (GPS) and MILES technology. This DIS-compatible system has the capability to link live with virtual and constructive simulations.

3. Systems Intended To Be Embedded

This category of stand-alone systems include those systems that are intended to be embedded but which, for cost or other reasons, have not been implemented. One example is the Electronic Warfare Intelligent Embedded Training (EWIET) system (Gluckman and Willis, 1994). This is a proof-of-principle demonstration of ET technology for the Navy's SLQ-32 EW system. The principle being demonstrated is the application of intelligent tutoring to ET. The demonstration is not implemented on the system but on a simulation of the system. The simulation runs on the same system (a multi-media personal computer) that runs EWIET and is intended to emulate shipboard training.

APPENDIX B.
ANNOTATED POLICY STATEMENTS REGARDING EMBEDDED TRAINING

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ANNOTATED POLICY STATEMENTS REGARDING EMBEDDED TRAINING

Department of Defense. (1996, 7 October). *Defense science and technology plan.* Washington, DC: Author.

> In the context of listing deficiencies and barriers to joint readiness, the following quote is relevant: "The principal barriers to more effective joint and combined staff training include the lack of interoperability among service and allied training simulations and models and the lack of tools and methods for assessment and feedback. Another barrier is the absence of an embedded training capability in C4I and weapons systems."

White, John P. (1996, 23 September). [Memorandum from the Deputy Secretary of Defense. Subject: Accelerating the Application of Embedded Training and Advanced Simulation Technologies.] Washington, DC: Author.

> This memorandum initiates a DoD-wide effort to determine how we can capture the potential for embedded training and advanced simulation technologies to reduce overall costs, and at the same time, improve readiness and increase military capability. While some work is already underway, we must place a higher priority on finding opportunities to apply these and other promising technologies that will help the Department realize their benefits as soon as possible . . . In that regard, I would like to set up a Training Coordination Group (TCG) that will focus on identifying opportunities to apply embedded training, advanced simulation, and other technologies . . .

WarNet XXI. (1996, 13 August). *WarNet XXI action plan* (Final Coordinating Draft). Washington, DC: Author.

> Army policy mandates the consideration and evaluation of embedded training as the preferred alternative among other approaches to incorporating training subsystems in the development of all Army materiel systems.

United States Army Training and Doctrine Command. (1996, 3 June). *Embedded training concept* (Draft TRADOC Pamphlet 350-70-XX). Washington, DC: Author.

Summary: This concept serves as the basis for technological and doctrinal initiatives that support the Army's ability to train using capabilities designed into or added onto its operational systems. It describes embedded training and provides the framework to incorporate it into Army vision and requirements documents.

Naval Surface Warfare Center. (1996, May). [Web site for BFTT Information Net (BIN).] Port Hueneme, CA: Author.

In describing the basic rationale for the BFTT, web site authors contend that it is an outgrowth of the Navy's Tactical Training Strategy, which itself is based on team training research and empirical studies over the last ten years. This strategy was articulated in the CNO message of December 1991: ". . . the ship when properly supported presents the most effective training site for appropriate operational and functional training. This allows the ships to train using their own equipment, system configurations, and operational/casualty procedures."

CINCLANTFLT/CINCPACFLT. (1996, 15 January). *Tactical training manual* (Instruction 3501.1A).

In developing training requirements that support warfighting capabilities, the following precepts were followed: "Wherever possible, conduct training on-board ship with organic training devices and installed equipment under supervision of shipboard training teams" (Chapter 5).

Force XXI. (1995, 23 October). Warfighter OPORD 1-95 (WARFIGHTER XXI). Fort Knox, KY: Author.

The goal of WF XXI is to use digital technology to maintain a continuous edge in projecting and employing combat power on future battlefields. Mirroring this effort must also be initiatives to embed the complex, combined arms, structured training of the future into the digitized force. The end state is the "digitized battlefield" to provide seamless, digital C2 capabilities for the entire fighting force.

Force XXI (1995, 15 June). *Warfighter XXI (WF XXI).* Fort Knox, KY: Author.

Currently, the large majority of all TADSS are non-system devices. The ultimate goal of Warfighter XXI is to drive the development of the technology that will support fully embedded TADSS in the prime systems. This shift in balance between system and non-system TADSS will require a closer link between prime system materiel development and TADSS development (Chapter 5).

Slatkin, N. (1995, 3 May). [Statement of the Assistant Secretary of the Navy (Research, Development, and Acquisition) before the House Appropriations Committee on Navy/Marine Corps Acquisition.] Washington, DC: Department of the Navy.

Hon. Nora Slatkin highlighted embedded training initiatives in her proposed FY96 S&T plan: "The computerized nature of modern naval systems enables us to embed system-based intelligent training technologies into operational systems. These training systems will significantly reduce direct training costs. Additional savings will be realized through reduced travel costs, reduced need for classrooms, and reduced associated logistics. By utilizing built-in training modes, we gain greater training effectiveness and the flexibility inherent in on-demand training capability available anywhere at any time."

Department of the Army. (1990, 30 May). *Army modernization training* (AR 350-35). Washington, DC: Author.

The training developers are responsible for identifying, planning, and coordinating the conduct of training to support Army modernization. The exact form of this training will be determined by the training developer in coordination with the combat developer. The use of embedded training to meet these needs should be given primary consideration . . . training that results from features designed and built into a specific end item of equipment to provide training in its use. It will not interfere with the operational requirements capabilities of the system, and it trains individual tasks through force level tasks as required.

Joint Technical Coordinating Group for Training Systems and Devices (JTCG-TSD). (1989). [Study plan for embedded training.] Washington, DC: Author.

According to this document the following is the Air Force's definition of embedded training: "A training capability which is designed into or added onto operational equipment."

C/NET Task Force on Embedded Training. (1985, 14 November). [OPNAVINST on embedded training.] Washington, DC: Department of the Navy.

Embedded training is defined as ". . . training that is provided by capabilities built into or added onto operational systems, subsystems, or equipment, to enhance and maintain the skill proficiency of fleet personnel" (paragraph 4.1).

Thurman, M., and Ambrose, J.R. (1987, March). [Policy and guidance letter from Vice Chief of Staff of the Army and the Undersecretary of the Army. Subject: embedded training.] Washington, DC: Department of the Army.

Embedded training is defined as ". . . training that is provided by capabilities designed to be built into or added into operational systems to enhance and maintain the skill proficiency necessary to operate and maintain that end item equipment." The Army's unambiguous policy is that ". . . ET will be included in all new and developing Army systems unless there are valid and compelling reasons not to do so."

APPENDIX C.
BIBLIOGRAPHY

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BIBLIOGRAPHY

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APPENDIX D.
SUMMARY DESCRIPTIONS OF EMBEDDED TRAINING SYSTEMS

APPENDIX D.
SUMMARY DESCRIPTIONS OF EMBEDDED TRAINING (ET) SYSTEMS

Service: Air Force

ET System Name: AN/GPS-T2

Parent System: Plan Position Indicator (PPI) displays of Air Defense Direction Centers (ADDCs)

Functional Description

The AN/GPS-TS was a pioneering ET device [circa late 1950's, before development of Semi-Automatic Ground Environment (SAGE)] that strapped onto PPI displays. The AN/GPS-T2 converted prerecorded films into signals that were interpreted as actual radar target blips. This is an example of ET "stimulation." An accessory to this system, the Anti-Countermeasures Trainer (ACTER) OA-1767, enabled the PPI to simulate the effects of electronic countermeasures (ECMs).

Assessment

Results from an evaluation of the system training program (STP), of which the AN/GPS-T2 was an integral part, indicated that performance of ADDC teams who trained on STP improved more than teams who did not train on STP (Jaffe, 1958). Also, the decision to fully integrate ET into the successor computer-based system (SAGE) was an indication of the success of the AN/GPS-T2.

Positive Features

- The use of AN/GPS-T2 was supported by an all-encompassing training program (STP) that included other features designed to improved training, such as a standardized debriefing procedure and an instructional sequencing strategy.

Negative Features

- Fidelity was limited by noninteractive targets. For instance, threat bombers continued to move on their predefined path even after they had been "shot down."

Service: Air Force

ET System Name: On Board Electronic Warfare Simulator (OBEWS)

Parent System: F-16 and F-15E aircraft

Functional Description

OBEWS is a strap-on system embodied in a pod strapped under the wing of the aircraft. This pod, which has characteristics of a advanced medium range air-to-air missile (AMRAAM), produces a threat simulation to radar warning receivers in flight. OBEWS comprises two major subsystems: the on-board subsystem (OBS) and ground support subsystem (GSS), which interact via an electrically erasable, programmable read only memory (EEPROM) module. Scenarios are loaded into the EEPROM module at the GSS. After a training flight, data downloaded from the EEPROM to the GSS are used to debrief.

Assessment

Initial testing (Glenn, 1989) of OBEWS indicated positive responses to the system. However, despite favorable public responses to the system, the Tactical Air Command (TAC) has been slow in adopting the system.

Positive Features

- Scenario information includes terrain data that simulate the effects of terrain masking.
- OBEWS targets can be mixed with simulated targets generated from ground sites.
- Pilots can react as they would to electronic warfare (EW) threats (jamming, chaff/flare launch, or terrain masking). Responses are recorded by the EEPROM module.
- GSS provides detailed and flexible replay. It allows compressed or real-time replay, comparison of the actual and the planned route, threat events, radar warning receiver (RWR) audio and symbology—all of which are correlated with aircraft position, attitude, terrain, and countermeasures status.
- Replay can be provided in standard planar view, two dimensional (2-D) shaded relief, or a three dimensional (3-D) view.
- Conversion time from training to combat operations mode is minimal, approximately 1 hour.
- In contrast to range-based simulations, OBEWS is nonradiating; thus, the system is invisible to electronic surveillance from potential adversaries.

Negative Features

- For safety considerations, only one aircraft can be trained at a time. That is, OBEWS does not simulate a situation where multiple aircraft, flying in close formation, are illuminated by a single threat radar beam.
- The simulation does not accommodate electronic counter-countermeasure (ECCM) capabilities.
- The pod degrades the aerodynamic characteristics of the aircraft.
- While fitted with OBEWS, the aircraft is not combat operational.

Service: Air Force

ET System Name: Semi-Automated Ground Environment (SAGE)

Parent System: Semi-Automated Ground Environment (SAGE)

Functional Description

The computer-based SAGE Direction Centers carried out the functions of several manual ADDCs. SAGE computers had embedded in them the ability to run computerized simulation scenarios through the system displays.

Assessment

Rowell (1962, cited in Parsons, 1972) tracked the performance of four crews, each comprising approximately 50 officers and airmen, as they trained on SAGE over a 2.5-month period. Even though scenarios were systematically increased in difficulty over that time, a variety of performance measures indicated substantial improvements over repeated practice trials. Unfortunately, this evaluation did not sort out the effects of the ET aspects of SAGE from the other aspects of the Systems Training Program (STP) in which the ET system was used.

Positive Features

- Like the manual STP program, the SAGE ET system was part of a comprehensive instructional system.
- The SAGE system captured and processed some—but not all—performance data needed for debriefing.

Negative Features

- SAGE ET system required substantial human trainer support.

Service: Air Force

ET System Name:

Parent System: World-Wide Military Command and Control System (WWMCCS)

Functional Description

WWMCCS is an older Joint-Service command and control (C2) system that was developed by the Air Force. The ET is fully embedded in the system's general-purpose computers, but it is used in training (as opposed to operational) mode only. The ET system incorporates simulation scenarios and computer-based tutorials.

Assessment

Warm et al. (1988) did not provide as much information about the WWMCCS as they did with other systems in their review. Nevertheless, they characterize the system as highly reliable and available for training within the constraints of operational needs. Users rate it as easy to use, with fast start-up and shut-down times. The individual computer-based modules are used often, much more so than the computer-based scenarios.

Positive Features

- The tutorials can run at some stations while the system continues to operate on others.
- The ET system includes a library of canned scenarios and computer-based instruction (CBI) modules.
- Switching between training and operation mode is fast (less than 1 minute).
- Units can author and store computer-based tutorials.
- Scenarios can be run over the WWMCCS network, thereby providing training in coordination among locations.
- The system has record-keeping capabilities that are used to determine the readiness of the WWMCCS network.
- Computer-based tutorials have automated performance measurement capabilities.

Negative Features

- Units cannot author simulation scenarios.
- Scenarios do not have automated performance measurement capabilities.
- Computer-based scenarios have no freeze, playback, or fast-forward capabilities.

Service: Air Force

ET System Name: Onboard Simulation (OBS)

Parent System: F-15B Flight Control System

Functional Description

Sponsored by the Air Force Wright Aeronautical Laboratories, OBS was originally designed for flight testing of the Integrated Flight and Fire Control (IFFC) system on the F-15B, which occurred between July 1981 and January 1983. It was originally conceived as an alternative to a "hot bench" unit, which is a test stand parked next to aircraft and used to generate test signals to aircraft subsystems.

OBS software is fully embedded in one of the aircraft's digital computers and generates dynamic targets via the pilot's heads-up display (HUD). It simulates air-to-air and air-to-ground gunnery and bombing operations. It normally used while in transit in a non-tactical environment but can be used on the ground.

Assessment

As of the writing of Warm et al. (1988), the OBS was an experimental system and had not been implemented in all active Air Force squadrons. In units where it was implemented, however, users rate the OBS as easy to use, with a single switch for engaging or disengaging the system in less than 1 minute.

Kocher (1984) documented two types of savings that OBS accrued during IFFC testing. First, it reduces or eliminates the costs associated with live training, including those related to towed or tactical targets and to ammunition and bombs. Second, it increases the number of encounters ("events") that can be performed per flight hour. With OBS, the system is simply reset after each encounter to prepare for the next. With real targets, lengthy set-up time is required to position the target and the attacker after each run.

Positive Features

- The OBS provides onboard scoring using the Air Combat Evaluator (ACE) software. Information is provided to the pilot via a Bullets-At-Target-Range (BATR) symbol (or "hot point"). For air-to-ground scenarios, BATR displays the pilot's bullet stream relative to the target. Also, during air-to-ground scenarios, BATR and ACE are used to compute predicted bullet hits and miss distance for bombing runs.
- OBS allows the simulation of head-on air-to-air encounters without the risk of mid-air collision.
- Activation and deactivation of OBS software takes less than 1 minute.
- OBS includes an extensive library of randomly accessed canned scenarios.
- OBS targets are more evasive than towed live targets can be.

Negative Features

- Visuals are to the field of view from the HUD. This seriously limits training for air-to-air combat.
- OBS does not simulate nonvisual stimuli that accompany firing (vibration and sound).
- The system has no scenario authoring feature. Scenarios can only be changed with avionics system upgrades.
- The system has no on-line scenario modification feature.
- Performance feedback is not stored and cannot be printed out.
- The system does not have scenario freeze, replay, or fast-forward features.
- When OBS is used, other aircraft are not allowed in airspace for safety reasons. Thus, multi-aircraft tasks cannot be trained.
- OBS requires substantial training to operate system.
- OBS cannot be used when aircraft is in operational status. Aircraft must be dedicated to training.
- OBS does not train missile firing tasks.

Service: Air Force

ET System Name: Airborne Operational Computer Program (AOCP)

Parent System: Airborne Warning and Control System (AWACS)

Functional Description

AOCP software, which is fully integrated into AWACS computers, presents simulated scenarios on- or off-line. The AOCP presents simulation scenarios through the six situation display consoles (SDCs) on the aircraft. ET is normally used after an aborted mission—when a subsystem (e.g., radar) fails and prevents the completion of the mission.

Assessment

AWACS is a reliable system and is normally available for operations and training, although training access can be restricted by flight demands. "AWACS ET is easy to operate from startup to shutdown" (Warm et al., 1988, p. F-4).

Positive Features

- In addition to off-line training, training can occur while aircraft is in the air and the AWACS system is in on-line, with no serious decrement to readiness. If on-line, the AOCP is automatically deactivated when AWACS receives an alert.
- AOCP can use canned scenarios.
- Crews can author and store their own scenarios.
- Scenario replay includes operator responses.
- System has scenario freeze, replay, and fast-forward capabilities.
- The system takes less than 1 minute to return from the training to the operational mode.
- AWACS can send simulated target data to other aircraft, ground stations, or shipboard C2 systems, thereby enabling training in coordination.

Negative Features

- Uploading scenarios takes a moderate amount of time (at least 51 minutes).
- Scenarios cannot be modified once started.
- Other than replay, system has no automated performance measurement.

Service: Air Force

ET System Name: Sentinel Byte Prototype Tutor

Parent System: Sentinel Byte

Functional Description

Sentinel Byte is an Air Force command, control, communications, and intelligence (C3I) system for planning air routes and analyzing air defense (AD) threats. The prototype tutor, developed by Mitre Corporation, provides an overview to the system, instructs operators on specific procedures for using Sentinel Byte to generate the threat picture, and provides on-screen checklists.

Service: Air Force

ET System Name: Computerized On-line Advising and Contextual Help (COACH)

Parent System: Portable Maintenance Aid (PMA) of the Integrated Maintenance Information System (IMIS)

Functional Description

COACH is a software application that can run on a personal computer (PC) as well as on its primary medium, the PMA. The PMA is a lightweight, hardened portable computer for use on the flight line. Although the PMA is limited by its small screen, poor presentation quality, and limited keyboard, it has access to the most of the components of IMIS.

COACH is designed to be used in the flight-line maintenance environment but not while maintenance is actually being conducted—that is, it is designed as a trainer, not as a job aid, even thought it is embedded in one. COACH is structured to present three levels of training: apprentice, journeyman, and craftsman. These different training levels vary in the amount of interaction between student and his virtual mentor, the "Coach." Although it is intended to be used in the PMA in a flight-line maintenance environment, its portability across computer media enlarges its application to other environments, such as classroom, ready room, and even home study.

As described by Wilson et al. (1996), it is a demonstration project to illustrate the training potential of IMIS using the PMA. COACH currently exists as a detailed description of requirements and suggested screens that could be used.

Service: Army

ET System Name: Abrams Full Crew Interactive Simulator Trainer (AFIST)

Parent System: M1-series tanks

Functional Description

AFIST is an ET system that is appended to a powered-down M1 tank. AFIST uses commercial off-the-shelf (COTS) technology to present computer-generated graphics and sounds to the turret and driver's compartment. All four tank crewmen use tank controls to practice precision and degraded gunnery skills.

Positive Features

- The system contains 500+ tactical engagements derived from the Tank Gunnery tables (FM 17-12-1).
- The system provides a detailed critique, which can be printed out for the crew.
- The AFIST training management system includes a training matrix that organizes the engagements into a progressively sequenced exercises and maintains a crew training history.

Negative Features

- Instructors cannot author new engagements.

Service: Army

ET System Name: Integral Operator Trainer (IOT)

Parent System: Homing All-the-Way Killer (HAWK) Air Defense Weapon System

Functional Description

The IOT is a simulator embedded in the HAWK system. Raytheon has developed a laptop computer-based system called the Advanced Scenario Generator (ASG). The ASG interfaces with the IOT.

Service: Army

ET System Name: Intelligent Embedded Operator Assistant (IEOA)

Parent System: HAWK Air Defense Weapon System

Functional Description

IEOA is an intelligent tutor that accompanies the HAWK embedded simulator—the IOT. Operational since 1987, the IEOA is regarded as one of the first real-world applications of intelligent tutoring systems.

Service: Army

ET System Name: Live Air Trainer (LAT)

Parent System: PATRIOT Missile System

Functional Description

LAT enables PATRIOT crews to use disabled systems to engage real targets. It simulates missile firing, missile flyout, and engagement of targets of opportunity and their destruction. LAT was scheduled to be available in the spring of 1986 (Strasel et al., 1988).

Service: Army

ET System Name:

Parent System: Forward Area Air Defense, Command, Control, and Intelligence (FAAD C2I)

Functional Description

FAAD C2I is an integrated computer hardware, software, and communications system for identifying aircraft, distributing C2I data among Air Defense Artillery (ADA) units and combined arms elements, giving early warning to rest of force, and alerting Air Force and rear area defenses about transiting enemy aircraft. The system provides an embedded simulation capability that replicates situations encountered in mission operation.

Service: Army

ET System Name: Air Ground Engagement System (AGES)

Parent System: AH-64 (Apache), OH-58 (Kiowa), and UH-60 (Blackhawk) helicopters

Functional Description

AGES is an appended, eye-safe laser simulation for simulating the effects of Hellfire air-to-ground missiles. It also allows aircraft to be engaged by ground weapons and other aircraft. As a member of the MILES family of devices, it is compatible with simulation systems (e.g., MILES 2000) used at Combat Training Centers (CTCs).

Positive Features

- AGES II records events for After-Action Review (AAR) purposes, identifying by player and weapon type.
- System simulates aircraft survivability equipment.

Service: Army

ET System Name: Training Interface Unit (TIU)

Parent System: Aquila Remotely Piloted Vehicle (RPV)

Functional Description

Designed by Rediffusion and Silicon Graphics, the TIU straps onto the system to provide the additional computing capacity needed to generate simulated imagery through the Aquila system display. The Aquila ET system trains the RPV mission commander, air vehicle operator, and mission payload operator.

Service: Army

ET System Name: Troop Proficiency Trainer (TPT)

Parent System: PATRIOT Missile System

Functional Description

Fully integrated into the PATRIOT's computer systems, the TPT simulates actual PATRIOT data while disabling the radar system—that is, it is strictly an off-line device. Each battery can train individually or be networked to simulate battalion-directed AD functions. The TPT mimics the institutional trainer (P-COFT), from which it can port simulation scenarios.

Assessment

The TPT is generally perceived as a success—that is, a well-designed ET system that is used often in garrison settings (Strasel et al., 1988). The users in Warm et al.'s (1988) study indicated that the TPT was easy to use and had relatively short start-up and shut-down times.

Positive Features

- ET was designed into the system.
- ET has minimal impact on system random access memory (RAM).
- Transition from training to operational mode and from operational mode to training mode is rapid (matter of minutes).
- The TPT includes a library of "canned" scenarios plus the ability to author new ones.
- The system provides feedback in the form of printouts that summarize engagement outcomes.

Negative Features

- Activation of ET disables radar and launchers.
- Feedback does not include information on operator responses.
- The library contains a relatively small number of canned scenarios, which means that users can quickly "learn the scenarios."

Service: Army

ET System Name:

Parent System: All Source Analysis System (ASAS)

Functional Description

ASAS is the Army version of a joint system for processing intelligence information and corresponds to the Air Force's Enemy Situation Correlation Element (ENSCE). Plans were made, at least in 1988, to embed a training system into ASAS.

Assessment

Evans et al. (1988) derived lessons learned from the design of ET for ASAS/ ENSCE. However, they provided no assessment of the resulting system.

Service: Army

ET System Name:

Parent System: Advanced Field Artillery Tactical Data System (AFATDS)

Functional Description

AFATDS was designed as a replacement for the Tactical Fire Direction System (TACFIRE). Its computer systems are more compact and user friendly. It provides the fire support portion of the Army Tactical Command and Control System (ATCSS), using its common hardware components and common operating environment (COE). AFATDS training includes both stand-alone and embedded systems. The embedded system has not been described in any detail.

Service: Army

ET System Name: Aircraft Survivability Equipment Trainer (ASET) III

Parent System: Aircraft Survivability Equipment (ASE)

Functional Description

The ASET III is a subsystem installed in Army aircraft or flight simulators to provide replication of AD threats during routine missions. In a training role, the ASET III activates the ASE, allowing aviators an opportunity to operate various countermeasures and employ appropriate tactics, techniques, and procedures (TT&P). Real-time feedback is provided to the aviator for learning and AARs.

Service: Army

ET System Name:

Parent System: Combat Service Support Command System (CSSCS)

Functional Description

CSSCS is the commander's combat service support (CSS) C2 system. It interfaces with the family of Standard Army Management Information Systems (STAMIS) currently fielded to the Army. A compact disk (CD)-based ET system provides three modes of training: training course (tutorial), scenario training (simulated battlefield environment), and free play.

Service: Army

ET System Name:

Parent System: Tactical Fire Direction System (TACFIRE)

Functional Description

The TACFIRE ET system has two functions. First, it provides computer-based tutorials—which were developed in PLANIT authoring language—for training TACFIRE operators. Second, it presents simulation scenarios for training small teams of computer and acronym operators in TACFIRE messages. The scenarios implemented on tape require these teams to complete and transmit TACFIRE messages correctly.

Assessment

The TACFIRE ET system received the most negative evaluation of all systems evaluated by Strasel et al. (1988). The TRADOC Systems Analysis Activity (TRASANA) documented that only a small minority of TACFIRE operators use it or have used it. Germas and Baker (1980) showed no difference between the computer-assisted instruction (CAI) mode of TACFIRE and the traditional mode of instruction on immediate and delayed paper-and-pencil knowledge test, and they indicated positive attitudes toward the system during its initial assessment.

Positive Features

- Although designed after the fact, the ET system is completely embedded in TACFIRE.
- The TACFIRE is a large computer system that is well suited to ET.

Negative Features

- TACFIRE ET uses the same user interface for training that is used for operations. This interface has been often criticized as not being user friendly.

Service: Army

ET System Name: Howitzer Improvement Program Embedded Training (HIP ET)

Parent System: Howitzer Improvement Program (HIP): M109A6 self-propelled howitzer

Functional Description

HIP ET is fully embedded in and delivered through the Automated Fire Control System (AFCS), which includes a visual display and 26 keys and switches to control the system and input data. The HIP ET presents computer-based tutorials and simulated scenarios. Both are intended for training individual artillerymen.

Assessment

Schopper et al.'s (1990) abbreviated assessment of HIP ET indicated positive subjective reactions to system during initial testing. Results from performance tests show soldiers with less ability committed more errors and took more time to complete computer-based tutorials. Feedback indicated that additional information and practice are needed to transition from tutorials to scenarios.

Service: Army

ET System Name: Multiple Integrated Laser Engagement Simulation (MILES)

Parent System: Armored fighting vehicles

Functional Description

The MILES is a family of training systems that simulate the effects of direct fire weapons. MILES provides the capability for force-on-force (FOF) and target engagement in a real-time environment. The MILES component for armored fighting vehicles (M1-, M2, and M3-series) is a strap-on device for emitting and detecting laser signals. When a vehicle fires its direct fire system at an opposing vehicle, the lasers replicate the trajectory of live ammunition. The receiver on the target vehicle picks up the firing laser and affects the laser system of the targeted vehicle—depending on the accuracy of the fires, the type of ammunition, weapons systems involved, a probability of kill factor, and several other factors like range and angle of fire. A new version of MILES (MILES 2000) takes advantage of new technology to produce a smaller, more invisible system that includes performance measurement capabilities.

Assessment

Compared to earlier methods of Tactical Engagement Simulation (TES), MILES drastically reduces the number of observer/controllers (O/Cs) required to observe and score performance ("training overhead"). ARI was involved in the initial user acceptance testing. They also participated ". . . in a later follow-up, after fielding, which identified specific problems the units were having, and worked with the TSM-TES to correct them. This implementation plan and effort for MILES-TES was the most complete and effective ever conducted by TRADOC" (ARI Newsletter, Spring 1995). The Project Director for MILES 2000 has stated on his Web page that "... MILES training has been proven to dramatically increase the combat readiness and fighting effectiveness of military forces" (3 September 1996).

Positive Features

- MILES 2000 will have a performance measurement capability.

Service: Army

ET System Name:

Parent System: Army Battle Command System (ABCS)

Functional Description

ET is implemented in one of three ABCS components: the Army Tactical Command and Control System (ATCCS), which is comprised of five Battlefield Functional Area Command and Control Systems (BFACS). Each BFACS has on-line help features, mini tutorials, and embedded interactive simulation scenarios, as well as technical manuals (TMs) and field manuals (FMs) on electronic media.

Service: Army

ET System Name: Improved Target Acquisition System-Training System (I-TS)

Parent System: Improved Target Acquisition System (ITAS)

Functional Description

ITAS is an add-on product improvement to the Tube-launched, Optically-tracked, Wire-guided missile (TOW) 2A/2B. IATS operates in two modes: (1) the ET mode, where the system can be used by itself to provide sustainment gunnery training and (2) the tactical engagement simulation mode, which provides capability to conduct FOF engagements with other MILES II/2000 systems. IATS presents simulated visual effects (i.e., launch obscuration, flyout, and burst on target) in gunner's sight.

Service: Army

ET System Name:

Parent System: Advanced Tank Armament System (ATAS) for Abrams tanks

Functional Description

ATAS is a collection of technologies for improving the weapon system capability of Abrams tanks. ATAS includes development of a new gun, thermal imaging system, extended range fire control system (FCS), and ET. Texas Instruments (TI) is developing the ET component, using digitized video displayed to each crew station. ET concepts are now under test in an ARSI testbed for evaluating future armored vehicle concepts.

Service: Army

ET System Name: Precision Gunnery System (PGS)

Parent System: Bradley Fighting Vehicle

Functional Description

The purpose of this strap-on ET system is to introduce precision gunnery effects and procedures in FOF tactical training. The system simulates 25-mm main gun, coaxial machine gun, and TOW missile effects. Fielding of PGS began in May 1995.

Service: Army

ET System Name: Tank Weapons Gunnery Simulation System (TWGSS)

Parent System: Abrams Tank

Functional Description

The purpose of this strap-on ET system is to introduce precision gunnery effects and procedures in FOF tactical training. The system simulates main gun and coaxial machine gun effects. Fielding of TWGSS began in May 1995.

Service: Army

ET System Name: TPQ-29 Trainer

Parent System: Improved HAWK (IHAWK) Missile System

Functional Description

The TPQ-29 is a strap-on, umbilical ET system that was developed long after the operational system had been implemented. The ET system—equipped with its own console for initializing and controlling training sessions—is mounted in a van that is connected by cables to the operational equipment. One system is issued per battalion and periodically rotated among batteries. Batteries are typically scheduled for two 16-hour training periods per month.

Assessment

Warm et al. (1988) documented several problems that apply to the TPQ-29. Because of strict State of Readiness (SOR) requirements, the IHAWK system cannot often be taken off-line for training. In some cases, actual hook-up times have been longer than a battery has for training. The IHAWK system must be retuned after use of TPQ-29. Low reliability of IHAWK has also limited the amount of time available for training. The strap-on nature of system has increased logistic requirements, adding unique parts and systems to IHAWK.

Positive Features

- TPQ-29 has scenario authoring capability.

Negative Features

- TPQ-29 can only be operated when the IHAWK system is off-line.
- System has no on-line control of scenario.
- It has no performance measurement capabilities.
- It does not communicate with other units to simulate coordinated tasks.
- Signals for TPQ-29 are lower in intensity that operational signals, requiring the user to increase the signal gain. Users think that this detunes the system, which contributes to their dislike of the system.
- System has no scenario freeze, fast-forward, or replay capabilities.
- Hook-up pins are difficult to use and susceptible to bending and breaking.

Service: Army

ET System Name: RAID tapes

Parent System: Missile Minder Command and Control (C2) System

Functional Description

The Missile Minder is a C2 system that controls NIKE, HAWK, and PATRIOT systems at the AD battalion or group level. The ET system is embodied in so-called RAID tapes that store, in tape cartridge form, scenarios for training. A second magnetic tape unit records results from simulated incidents. The ET system is used for training Missile Minder teams and performing readiness evaluations.

Assessment

According to Warm et al. (1988), users judge the Missile Minder ET to be easy to use and quick to start-up and shut-down. However, the system is only infrequently available for training (less than three times per month).

Positive Features

- Simulation fidelity is considered very good, with no notable difference between simulated and operational imagery.
- Performance data can be stored and/or printed out.
- A library of canned scenarios is provided with the system.
- System has playback feature, by restarting tape (but only at the beginning).

Negative Features

- Although ET system can be used on-line in concept, it is not used on-line in practice because it would input simulated targets as real targets.
- Users do not have ability to author scenarios.
- Performance data is limited to system hits and misses.
- System has no scenario freeze or fast-forward capabilities.

Service: Army

ET System Name:

Parent System: Crusader self-propelled howitzer and resupply vehicles

Functional Description

The Crusader is a 155 mm howitzer system currently under development. It comprises a self-propelled gun and independently controlled resupply vehicle. Designed to replace the Palladin, the Crusader will incorporate an advanced gun propulsion system (liquid propellant), automated ammunition handling, rearm and refuel under-armor capability, advanced fire control, and diagnostic/prognostics. In particular, the Crusader system will have ET for individual and crew tasks to reduce the need for live-fire training. The ET system will be Distributed Interactive Simulation (DIS)-compatible so that the vehicles can participate in FOF simulations and Synthetic Theater of War (STOW) environments.

In addition, the system will include an embedded decision aid to automate routine information processing functions, while helping the crew anticipate problems—such as low ammunition or fuel levels—and providing appropriate courses of action. The aid will constantly evaluate the factors of mission, enemy, troops, terrain, and time (METT-T) but will filter the information to the crew, providing only what they need to know. The system is already being tested in soldier-in-the-loop simulations. The date of the first unit to be equipped with Crusaders is FY 2005.

Service: Joint

ET System Name:

Parent System: Joint Communications Planning and Management System (JCPMS)

Functional Description

The JCPMS will provide an automated, systems management capability to assist the Commanders in Chief (CINCs), Combined Joint Task Forces (CJTFs), and Joint Task Force (JTF) component Commanders in communications planning and execution. The mission-needs statement for this system states that sustainment training needs will be met with ET (on-line help features) or "the most cost effective media."

Service: Joint

ET System Name:

Parent System: Joint Collection Management Tools (JCMT)

Functional Description

JCMT is the DoD Intelligence Information System (DoDIIS) migration system for all-source collection management. National, theater, and tactical organizations of all Services will use it. It is a software-only system that is scheduled for implementation in two versions or "capabilities packages" (CPs).

CP 1 is scheduled for release in December 1996. CP 2 is scheduled for release in April 1998 and will provide embedded instruction and help features.

Service: Joint

ET System Name:

Parent System: Joint Combat Information Terminal (JCIT)

Functional Description

JCIT, under development by the Naval Research Laboratory (NRL), is an aviator commander's C2 system. There are plans to include ET features into JCIT, including embedded instruction, help features, and extensive built-in test (BIT) capabilities to diagnose faults to a replaceable assembly and to guide the user in the replacement procedure.

Service: Navy

ET System Name: Video Signal Simulator (VSS)

Parent System: Navy Tactical Data System (NTDS)

Functional Description

VSS is a strap-on signal generator for simulating radar signals on the NTDS console.

Assessment

"Generally, the system users indicated that the VSS was a very good training system when it was working correctly" (Hoskin et al., 1989, p. 24).

Positive Features

- Can be used both in port and at sea, although it is used more often at sea.
- Users can create scenarios to their own liking (a popular feature).
- Simulated signals can be mixed with real-world video when ship is underway; this feature is not often used because of safety considerations.
- VSS interfaces with weapons systems (to an extent).
- Scenarios can be "frozen" at will.
- VSS has automatic performance measurement capabilities. Tracking accuracy is measured and stored for three contacts; performance is scored on 0–100 scale.

Negative Features

- Greatest criticism was the simulator's low-fidelity simulation of generic radar signals with limited environmental effects (video is "too clean"). Other specific fidelity problems include the lack of land-mass simulation (not a serious problem at sea) and simulation of jamming, chaff, and cloud formation effects.
- Second major criticism was the inability of the system to interface with all elements of the Combat Information Center (CIC), particularly sonar, EW, and Automatic Detector Tracker (ADT) systems. The result is that the CIC cannot be realistically exercised.
- Simulation of contact is limited to only three turn rates.
- There are no "canned" scenarios. Users must enter data to initiate each scenario run. This was a general complaint of users.

Service: Navy

ET System Name: Combat Simulation Training [formerly, Test] System (CSTS)

Parent System: Radar and Fire Control Systems (FCSs) on DDG-933 guided missile destroyers

Functional Description

The previous version of CSTS was a strap-on system, which was stationed pierside and connected to the ship by cables. The present system is "fully embedded" and can be used on- or off-line while the ship is at sea. It is a dual-purpose system, providing simulation scenarios and a test function for sensor station displays and weapon system equipment. It simulates radar images and "stimulates" the ship's sonar system to provide sonar images. The systems that interface with CSTS include Command and Decision (C&D) System, Radio Communications System (RCS), Surveillance and AIMS System (SAS), Gun Fire Control System (GFCS), Missile Fire Control System (MFCS), the Underwater Fire Control System (UFCS), and ships log and gyro systems.

Assessment

"The [previous] DDG-993 version of the CSTS was found to have serious problems in supporting training activities. This is due mostly to the fact that the system was designed as a test set and not as a training system" (Hoskin et al., 1989, p. 40).

"The first-generation CSTS provide effective training, but it was not considered a practical trainer because it took a full day to set up and check out the device and several hours to disconnect" (Warm et al., 1988, p. 24).

The newer version still has problems (Warm et al., 1988), including increased major pieces of equipment and resulting maintenance requirements and lack of performance measurement capabilities. However, ". . . the CSTS is, by itself, a simple system to operate, but start-up and shutdown times are over one minute" (Warm et al., 1988, p. I-9).

Positive Features

- New version runs canned scenarios. It also provides the training officer the ability to author custom-designed scenarios and store them on disk.

Negative Features

- The earlier version of CSTS had to be used with other simulation systems (e.g., VSS, sonar target generators) for training applications.
- The earlier version did not have any instructional support features—that is, performance measurement capabilities, scenario authoring capabilities, and freeze or replay features.

- The newer version also does not include performance measurement, feedback, or report generation capabilities (although some mission data can be retrieved from the NTDS).
- The newer version does not include scenario freeze, replay, or fast-forward features.
- Operating the newer version of CSTS precludes consoles selected for training from performing operational functions.
- In newer version, entities simulated on Link-4 and Link-11 communications networks are not communicated to other consoles.
- New version of CSTS has suffered from logistics and maintenance problems.

Service: Navy

ET System Name: AEGIS Combat Training System (ACTS)

Parent System: AEGIS Weapon System on CG-47 class cruisers

Functional Description

ACTS, which is fully embedded in the AEGIS system, presents simulation scenarios for training functions related to the C&D System, Weapons Control System (WCS), and FCS. ACTS sends data directly to the AN/SPY-1 radar. Within ACTS is the Computer-Aided Submode Training (CAST) system, which provides computer-based tutorials for initial training of AEGIS operators.

Assessment

"Reports obtained from Fleet users indicate that ACTS is a highly effective and desirable means of training . . . Overall, the ACTS capability is a very good example of what an ET system should attempt to achieve" (Hoskin et al., 1989, p. 39).

Positive Features

- ACTS can mixed simulated input with raw real-world video.
- ACTS has a variety of canned scenarios, which allows flexibility in content and size of team being trained.
- Canned scenarios can be altered manually on-line (but alterations cannot be saved).
- ACTS can generate 50+ surface and air contacts.
- ACTS trains all CIC stations.
- ACTS can be used for multi-ship training by transmitting symbology and raw video to other participants.
- ACTS has capability to printout overall team performance in terms of missile accuracy and kills sustained by ownship.
- ACTS has scenario playback feature (but no freeze or fast-forward).
- ACTS start-up time (5 minutes) and shutdown time (less than 1 minute) are moderate.
- CAST lessons are hierarchically arranged.
- CAST includes performance measurement in form of end-of-lesson tests.
- CAST maintains student records.

Negative Features

- CAST cannot mix real-world and simulated video.
- Use of CAST degrades system performance by taking consoles out of operation for training.
- ACTS has no scenario freeze and fast-forward capabilities.
- CAST does not include help features.
- Users see CAST as suitable only for initial training.
- Custom-designed ACTS scenarios cannot be saved.
- ACTS has no automated performance measurement or trainee record keeping system.

Service: Navy

ET System Name: Automatic Detection Tracking System Simulation (ADSIM)

Parent System: Automatic Detector Tractor (ADT) and Weapons Direction System (WDS) on surface ships

Functional Description

ADSIM, which is designed for both weapon system tests and training, uses simulated air radar targets from ADT to train weapons coordinators and weapons system teams. It allows "full integration" of ADT with the WDS.

Assessment

"Generally, users felt that the system provided adequate training for the individuals and subteams" (Hoskin et al., 1989, p. 37).

Positive Features

- ADSIM provides both canned scenarios and the ability to author (but not to store) scenarios.
- Canned scenarios are ordered by difficulty to adapt to entry-level and more advanced operators.

Negative Features

- Video has minimal realism with no jamming or interference simulation or other environmental conditions. Users felt the screen was "too clean."
- System cannot be linked with the VSS to provide full CIC training.
- ADSIM cannot store locally authored scenarios.

Service: Navy

ET System Name: AN/BQR-T4 Sonar Target Simulator

Parent System: AN/BQR-21, -20, -19, -15 sonar and fire control systems of ballistic missile and attack submarines

Functional Description

This ET system generates targets by stimulating the front-end of the sonar system just after the hydrophone. The AN/BQR-T4 models 41 contacts and has an accompanying tape mechanism that simulates sonar acoustics.

Assessment

"Generally, users indicate that the BQR-T4 is a fairly effective and reliable mechanism for training. Realism for the system was deemed adequate for most training, but could use some improvements" (Hoskin et al., 1989, p. 35).

Positive Features

- Users are most pleased with ability of system to integrate other tactical and weapons stations for full-team training.
- It allows adjustments to contact intensity, video fading, and controllability of contacts throughout the scenario.
- System allows freedom to custom-design scenarios but not to store them.
- It simulates environmental conditions by including the characteristics of seven different oceans.
- BQR-T4 allows the mix of real world with simulated inputs and contacts.
- System can receive ownship movement information or create that information to simulate movement.
- BQR-T4 can freeze and restart scenario to provide instruction and feedback.

Negative Features

- Principal criticism is that system does not simulate effects of ownship motion on target motion and bearing, thus limiting ability to drive ownship from sonar and to mix real world with simulated targets.
- Using system ties up a few sonar consoles, limiting operational capabilities somewhat.
- There are limitations on the maximum number of simultaneous contacts.
- No canned (preprogrammed) scenarios are provided.

- Active contacts must be constantly manipulated to achieve acceptable realism; system should be automated.
- Users have identified a need to simulate additional environmental effects on sonar characteristics, including bottom type, temperature, depth, time of year, and layer effects.
- System does not simulate weapons firing effects to permit extended operational training.
- System does not have performance measurement capabilities. In particular, users want a record/replay feature.

Service: Navy

ET System Name: AN/SQS-56 Target Simulator

Parent System: AN/SQS-56 receiver and console on FFG-1 and FFG-7 class frigates

Functional Description

The AN/SQS-56 is a fully embedded system that injects simulated sonar threat targets into sonar consoles. It is often used with text-based Operational Readiness and Assessment Training System (ORATS) to create training scenarios.

Assessment

Results indicate that the AN/SQS-56 simulation capability is an effective means for training, particularly when combined with ORATS [Operational Readiness Assessment and Training System] lessons and the accompanying performance measurement guides" (Hoskin et al., 1989, p. 34).

Positive Features

- System can mix simulated with real-world targets, which is viewed as desirable and not a safety hazard.
- System can simulate fades going below the layers with a variable contact intensity adjustment.
- System is effectively integrated with fire control and NTDS, providing full team

Negative Features

- Simulator does not have any preprogrammed scenarios.
- High-fidelity simulation effects require extensive data inputs and manipulations of contact characteristics during scenarios.
- Simulation of NTDS inputs limited to contact symbology (i.e., no video).
- Inability to include passive acoustics was major criticism.
- There are no preprogrammed or "canned" scenarios, and there is no capability to custom design scenarios to needs.

Service: Navy

ET System Name: In-Flight Trainer (IFT)

Parent System: F-14 aircraft

Functional Description

The IFT is software embedded in the F-14's central computer. It presents simulation scenarios to train pilots and radar intercept officers to deploy missiles against radar contacts. (No gatling gun tasks are trained.) IFT uses aircraft systems, with no additional equipment required. Scenarios are stored in read only memory (ROM) and present targets flying on preprogrammed paths. Synthetic targets are principally presented on the radar intercept officer (RIO) screen.

Assessment

The F-14 is a reliable system that is usually available for training. "Operating the IFT is very simple, requiring minimal effort on the part of the crew members. The IFT initializes and shuts down almost instantaneously" (Warm et al., 1988, p. G-4).

Positive Features

- IFT simulates radar, identification of friend or foe (IFF), ECM, and ECCM equipment with fairly high fidelity.
- Activation of IFT is virtually instantaneous, requiring one switch action by pilot and three by the RIO.
- IFT uses canned scenarios, which can be randomly selected by system, or the crew can select specific scenarios.
- System provides hit/miss data to crew.

Negative Features

- Scenarios are stored in ROM and cannot be authored. ROM-based scenarios are difficult to update—limited to only major software upgrades.
- Performance data cannot be stored on magnetic media or printed out on paper; this precludes use of debrief site.
- System has no scenario freeze, replay, or fast-forward capabilities.
- IFT cannot send simulated targets over commo net for coordinate training with other units.
- (As of 1988) IFT's lack of memory limits the number of scenarios that can be stored and their complexity.
- Fidelity does not permit training of air-to-air gunnery with gatling gun.

Service: Navy

ET System Name: Performance Measurement and Evaluation (PME) for Sonar Systems

Parent System: Sonar systems on surface ships

Functional Description

PME is a strap-on tape recorder system that records and plays back sonar contacts (video), accompanying acoustics, and voice annotations of real-world sonar operations. These tapes are normally evaluated by shore-based experts.

Assessment

"Results indicate that PME as a stand-alone means of training is basically ineffective . . . [but if used with a target generator]. . ., it provides an extremely useful capability"(Hoskin et al., 1989, p. 33).

Positive Features

- PME provides an excellent means for evaluating performance.

Negative Features

- Use is limited by the fact that playback is through the sonar console, thereby eliminating all operational capabilities. This limits its usefulness at sea.
- PME is not sufficient for presenting training. At a minimum, it must be used in conjunction with target generators.

Service: Navy

ET System Name: Unit 34, Sonar Target Generator

Parent System: AN/SQS-53 sonar consoles and NTDS consoles on surface ships

Functional Description

Unit 34 is a strap-on system for generating sonar targets. It injects sonar contacts (stimulates), sonar consoles, and NTDS consoles. Signals can vary in intensity and noise be imbedded in many environmental conditions.

Assessment

"Generally, Unit 34 is judged to be a fairly adequate training device for sonar operations" (Hoskin et al., 1989, p. 32).

Positive Features

- Controllability of contacts and ability to simulate environmental conditions are highly regarded aspects of system.
- Scenarios can be authored at the initiation of training.
- Scenarios can be frozen.

Negative Features

- Complex environmental conditions can only be simulated by constant manual inputs. System would benefit from automation of conditions.
- There are no canned scenarios. All scenarios must be pre-planned and input into the system.
- Freezing scenarios can lead to unexpected results (e.g., restarting the scenario).
- Each console used by Unit 34 reduces the operational capabilities of the system.
- The system is unable to mix real-world and simulated video for training at sea.
- Unit 34 does not interface with Mk 116 FCS that would allow team training of fire control.
- Unit 34 has no performance measurement capabilities.

Service: Navy

ET System Name: Operational Training Software (OTS)

Parent System: AN/SLQ-32 console on surface ships

Functional Description

OTS simulates EW signals through the tape drive on the AN/SLQ-32. The system includes a total of three pre-recorded tapes, each containing three simulation scenarios.

Assessment

"Results of the analysis with system users indicate that the OTS is an average-to-poor means of training EW operations" (Hoskin et al., 1989, p. 29).

Positive Features

- Tapes can be played at 10X as well as 1X speed for scenario presentation.

Negative Features

- OTS requires the same console and tape drive as operational system; thus, it requires that the SLQ-32 to be taken out of operational status. This severely restricts the usability of the system.
- Training tapes have not been revised in accordance with operational upgrades.
- OTS does not interact with any other system, as the AN/SLQ-32 would in the operational mode. In particular, the system should interact with NTDS Light Airborne Multi-Purpose System (LAMPS) Mk III, electronic support measure (ESM), and the EW supervisor station to provide EW countermeasures.
- The simulations low fidelity is judged inadequate for training experienced operators. The simulation does not include friendly signatures or noise or audio/acoustics and includes only a few hostile signatures.
- There is no capability to author or edit the "canned" scenarios on tape.
- Scenarios "frozen" for any reason must be restarted at the beginning of the tape.
- OTS has no performance measurement capabilities.
- OTS has no capability to mix live and simulated targets.

Service: Navy

ET System Name: Sonar Target Signal Simulator (STSS)

Parent System: AN/SQS-53, -53A sonar consoles on anti-submarine warfare (ASW) ships and destroyers

Functional Description

STSS is a strap-on device for simulating the visual and audio input to train sonar operators and teams in ASW exercises.

Assessment

"Results of the analysis with system users determined that the STSS is not judged to be a usable system . . .The ships that had STSS did not use it, and little specific information on its capabilities was available" (Hoskin et al., 1989, p. 27).

Positive Features

- Users can create their own scenarios.
- STSS can simulate some weapons being fired at ship.
- STSS can include some environmental effects.

Negative Features

- The primary objection is that the STSS runs much too fast to be realistic.
- Operational equipment must be specially aligned for the STSS training run.
- There are no canned scenarios. All scenarios must be pre-planned and input into the system.
- Little or no documentation exists.

Service: Navy

ET System Name: Training Module

Parent System: Joint Maritime Command Information System (JMCIS) and the Navy Tactical Command System (NTCS)

Functional Description

Under development by NRL, the training module offers the following capabilities: to allow the trainer to author ET sessions using NRL's Presentation Authoring Language (PAL), to present computer-based tutorials to trainees, to present dynamic scenarios to trainees, and to create and present sessions that integrate tutorials and scenarios.

The ET system is fully embedded in that software and calls relevant library functions within the parent system. Although training and operational computing can proceed simultaneously, the training module does not conflict with operational data or processes.

Service: Navy

ET System Name: Lesson Translator (L-TRAN)

Parent System: Naval Tactical Data System (NTDS)

Functional Description

L-TRAN is an embedded computer-based tutorial about NTDS consoles, symbology, and operation. It provides entry-level and sustainment training for NTDS operators on Navy carriers, cruisers, destroyers, and frigates.

Assessment

"Reports obtained from Fleet users indicate that the L-TRAN is a highly effective and desirable means of training" (Hoskin et al., 1989, p. 22).

Positive Features

- Provides individualized instruction that requires little supervision.

Negative Features

- Requires that multiple NTDS computers be taken out of operation. A minimum of 4 (out of 20) consoles are required for training, which limits use of ET at sea.
- Initiation of ET involves tape loading and manipulations requiring several minutes.

Service: Navy

ET System Name: SPA-25G Embedded Training System (SETS)

Parent System: AN/SPA-25G Radar Repeater Console

Functional Description

SPA-25G is a microprocessor-based system that can display any radar image generated within the Radar Display and Distribution System (RADDS). SETS is a proof-of-concept demonstration to show how an ET system would be used with this console. SETS is made up of three components: (1) the SPA-25G, an off-the-shelf radar signal simulator (Buffalo Computer Graphics RS-11), (2) a Zenith 248 DOS-based computer, and (3) an interface (RS-232) between the computer and simulator. SETS is designed to train individual operator tasks in four areas: (1) equipment proficiency, (2) radar navigation, (3) air intercept control, and (4) anti-submarine air control.

Assessment

The system has not been formally appraised, but Lacy, Ellis, and Madden (1990) offer the following cost analysis: "Instructors at "C" schools for air controllers estimate that SETS may reduce attrition by 50 percent. Given that the throughput at the school is 58 students and each student costs $30K to train, SETS is saving $870K per year (29 × $30K).

Positive Features

- SETS has the capability to create and store scenarios.
- System records and manages student performance data.
- During replay, the students and the instructor can compare student performance against some "ideal" target or standard that can be preprogrammed by the instructor.
- SETS has capability to freeze, replay, and play at faster or slower than real time.
- System provides printed feedback for student.
- SETS can record all voice dialogue that occurs during a training session.
- Scenario generator has "rehearsal" feature, where the developer can view the scenario as it is being developed.

Negative Features

- The system does not have voice recognition and synthesis capabilities. Therefore, "pseudo-pilots" are needed to role play for air control tasks. Pseudo-pilot errors make evaluation of student performance more difficult.

- Scenario generator requires the input of detailed data, such as position, bearing, and velocity. Graphical authoring features that allows developers to place aircraft directly on the PPI would make scenario development faster and easier.
- The RS-11 simulator was not designed for air control tasks and, consequently, lacks fidelity in that regard.

Service: Navy

ET System Name: Interactive Multisensor Analysis Training (IMAT)

Parent System: [Shipboard anti-submarine warfare (ASW) systems]

Functional Description

The current version of IMAT is a "scientific simulation" that trains sonar technicians and aviation warfare system operators in the fundamental concepts related to their jobs. It is designed to facilitate the acquisition of high-level cognitive skills that are normally acquired through extended on-the-job training. Although it is presently a stand-alone simulation, there are plans to develop an onboard version, which would include high-fidelity databases, near-real-time simulations, and visualizations for training tactical planning and reconstruction. The onboard version extends the IMAT concept from operator training to training an integrated Commanding Officer (CO)/Executive Officer (XO)/Sonar team.

Service: Navy

ET System Name: Organic Combat System Training Technology (OCSTT) Simulation System

Parent System: FFG-7 tactical systems

Functional Description

The OCSTT Simulation System is a technology demonstration designed to replace the pierside Device 20B5 with modern technology that is substantially cheaper and that converts the system to a shipboard training device, or what the authors term an "organic training system." The system maintains approximately 70 percent of the older device's functionality.

An important improvement is the incorporation of DIS capabilities. The target for transitioning this technology is the Navy's Battle Force Tactical Training (BFTT) system. Hardware costs of OCSTT were less than $200K, compared to more than $10M for Device 20B5.

Service: Navy

ET System Name: Device 20B4/B5

Parent System: FFG-7 and other surface ships

Functional Description

Built by AAI Corporation, the 20B4 and 20B5 are umbilical pierside ET systems that can be connected to as many as six ships for simultaneous training. They "stimulate" radar, communications, and EW and ASW receivers. They also "simulate" weapon systems (guns, torpedos, missiles) and decoy systems. The training focus is on team—rather than individual operator—training. Both systems use carry-on boxes and umbilical cords attached to a van parked near the pier. Whereas the 20B5 supports only FFG-7 training, the 20B4 supports training on other types of ships and has limited support for AEGIS capabilities. The van can drive DIS scenarios that are compatible with BFTT training performed at sea. The 20B5 system costs in excess of $10M.

Assessment

According to Stratton et al. (1996), the 20B5 ". . . is a proven training system and has a good reputation with the fleet . . . The interface points with FFG-7 tactical systems have been proven to work many times over" (p. 11).

Service: Navy

ET System Name: Training Alarm Controller (TAC)

Parent System: United Kingdom Polaris Fire Control System (FCS)

Functional Description

TAC is a fully embedded system that simulates failures in the Polaris FCS. To use the TAC, the FCS must be operating so that the gyros are energized and signals are received from the guidance system. Faults are simulated by controlling the relays that would be activated in the event of a real fault—a "stimulation" of sorts. The TAC is used to train the Weapon Engineer Officer (WEO) and his team in procedures related to failures in the countdown and launch sequence. TAC is usually used with the Patrol Analysis Recording System (PARS), which is a tape recorder for recording communications and pen event recorders.

Assessment

"The consensus is that, despite the shortcomings [listed below], TAC is a valuable item of equipment. However, due to the way it is used, no quantitative data are available on its actual effectiveness in imparting and maintaining skills" (Annett, 1990, p. 9). TAC is used with PARS during Weapon Systems Readiness Tests (WSRTs), which occur at irregular intervals but average about once per week during the submarine patrol. Results are not given to crew; rather, they are provided to the Ministry of Defence. Less formal exercises are performed by the weapon systems crew during Independent Exercises (INDEX) which occur at sea in preparation for patrol. The WEO maintains these records for training purposes.

Positive Features

- FCS shows indicator lights operating as they would with an actual fault. Although the TAC offers less fidelity than shore-based tactical simulators, it has been estimated that 70 percent of the faults occurring during missile launch countdown can be reproduced on TAC at sea.

Negative Features

- Location of TAC is inconvenient and limits its use, and surprise faults are virtually impossible. Access to the system is tolerably inconvenient for the WEO but intolerably inconvenient for an additional "sea riding" evaluator.
- It does not fully train or test the entire team. Training is limited to the weapon system team and, during INDEX, does not include the WEO who conducts the training and evaluates his team.
- The PARS system is used only for WSRTs, not for individual feedback.

- Team members can see fault being inserted into the system. The type of fault is hidden by a metal flap, but the fact that a fault is being input cannot be hidden.
- Some power fault indications cannot be simulated by TAC.
- There are fears that TAC contributes wear-and-tear on the FCS relays. Specifically, it may induce false positive indications caused by a sticking relay.
- Forgetting to reset fault indicator may lead to a false positive indication, although this can easily be avoided.
- Technical documentation is outdated and inconvenient to access. It is buried in longer documents on operation of the FCS.

Service: Navy

ET System Name: Sonar Operator Trainer 14E35 SN 2/3, 14E35C SN 4, and 14E35C SN 5

Parent System: Sonar Systems: AN/SQQ-89(V)1/2, AN/SQQ-89(V)2/4, and AN/SQQ-89(V)6/9

Functional Description

Located at the Fleet Anti-Submarine Warfare Training Center Pacific, this embedded stimulation systems is used in conjunction with SQQ-89 Interactive Courseware (ICW) training devices built by NAVSEALOGCENDET. These trainers teach sailors in the Sonar Technician (ST) rate and are very expensive, high-fidelity devices that use a combination of shipboard equipment and simulation/stimulation equipment.

Service: Navy

ET System Name: Electronic Warfare Intelligent Embedded Training (EWIET)

Parent System: SLQ-32 Electronic Warfare (EW) console

Functional Description

EWIET is a proof-of-concept demonstration; that is, it is not yet embedded in the operational system. It is currently implemented on a computer simulation of the SLQ-32 display. The process control architecture for the EWIET is the Knowledgeable Observation Analysis-Linked Advisory System (KOALAS), which models the human's tactical situation assessment and provides context for sensor fusion systems to initialize and maintain this assessment.

Service: Navy

ET System Name: Advanced Embedded Training (AET)

Parent System: AEGIS Weapon System on CG-47 class cruisers

Functional Description

AET—a research and development (R&D) 6.2 project for the Naval Air Warfare Center (NAWC)—is part of an Advanced Technology Demonstration (ATD) to integrate human performance technologies in AEGIS Combat System and Combat Training System. The prototype will be designed to train the CO, the tactical action officer (TAO), the combat systems coordinator (CSC), the anti-aircraft warfare coordinator (AAWC), the tactical information coordinator (TIC), the identification coordinator (IDC), and the electronic warfare supervisor (EWS). It will be supported by a training supervisor or scenario manager. The eventual product will provide an adjunct to the ACTS.

Assessment

A preliminary estimate by system developers was that the ". . . net result of this ATD for the fleet will be a vastly improved capability for ships to independently conduct comprehensive, consistent, timely, and effective team training in-port and at-sea . . . the AET system will significantly reduce the requirements for assignment of Afloat Training Organizations and AEGIS Training Support Group training support personnel to ships, which could result in a $1.5M/year cost savings. Moreover, the expected level of training enhancement is a 25% to 40% step improvement in team performance as determined by validated measures of effectiveness" (NAWC, 1996).

Positive Features

- AET will provide operator and team performance measurement.
- AET will provide diagnosis/assessment of performance.
- AET will provide corrective/facilitative feedback and computer-assisted coaching.

Service: Navy

ET System Name: Radar Electromagnetic Environmental Simulator (REES-204)

Parent System: AN/SPS-48 radar console on surface ships

Functional Description

REES is a built-in system that generates simulated radar targets to train operators and teams on systems in New Threat Upgrade Ships. The REES signal stimulates the radar receiver and can be received by any console that gets SPS-48 input. The REES is scheduled to be replaced by the Radar Environment Simulator System (RESS).

Assessment

"The REES System was evaluated by users as a fairly effective means of training radar operators and teams" (Hoskin et al., 1989, p. 28).

Positive Features

- Ease of use and system initiation were often cited as key determinants of REES usefulness.
- Number of targets (9) and controllability of these targets were viewed as desirable features.
- It allows mixing of real-world and simulated video, thereby increasing its usability at sea.
- It is a fairly high fidelity system, accurately simulating acceleration/deceleration rates and jamming, and emulates some environmental noise.
- Users can create their own scenarios.
- Trainers can freeze, slow, and speed up scenarios.

Negative Features

- Greatest criticism is that it does not interface with IFF, missile control, and other radar systems to allow training of the Combat Information Center (CIC) team.
- No documentation exists. The users were personally trained by contractors.
- Simulation lacks chaff and other radar sources of interference.
- The system does not have capability to create and reuse "canned" scenarios.
- The system has no performance measurement capabilities, although users viewed this only as a nonessential ("nice to have") feature.

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13. ABSTRACT *(Maximum 180 words)*

Embedded training (ET) refers to a training capability built into operational equipment. This document gives examples of training technologies commonly considered to be examples of ET, addresses the military interest in ET, describes ET's advantages (e.g., the ability to train at home station and during unit deployment) and disadvantages (e.g., the increase of weight, complexity, and wear and tear on operational equipment), and assesses the utility of ET technology. One of the appendixes discusses the types of ET systems and gives examples, and another appendix presents summary descriptions of ET systems. According to the authors' review of the literature, ET is effective and generally acceptable; however, little valid and reliable empirical data exist on ET's cost and effectiveness. The authors also conclude that defense policy should continue to favor ET as a requirement in new weapon systems until it is ruled out in any particular case by careful review of its probable effectiveness and cost.

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